Quantification of Rural Accessibility and Development of a Need-Based Approach for Rural Road Network Planning

THESIS

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CERTIFICATE

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(K. Shalini)

Abstract

Accessibility in rural areas may be characterized and quantified at distinctive levels – regional and habitational. The regional accessibility gives a wide comprehensive view about overall accessibility in different nations, states, districts and blocks which help in positioning them according to their accessibility levels. Habitational level accessibility gives accessibility levels of each habitation to different sectors. They mirror the issues confronted by the villagers in getting to the essential or social needs. Quantifying accessibility at both the levels are valuable for planners and decision makers. In this study accessibility has been quantified at two different levels.

Rural Access Index (RAI), one of the indicators developed by the International Development Association (IDA) has been utilized to find accessibility at regional level. The indices were also determined as per Pradhan Mantri Gram Sadak Yojana (PMGSY) definition of accessibility. This method has been used to find out the contribution of the construction of all-weather roads on improving accessibility in rural areas at regional level. As a case study, PMGSY roads viz., all-weather roads have been considered in this study. RAI has been determined with and without the presence of PMGSY roads as the difference will show the improvement in accessibility levels made due to these roads. Considering the fact that the accessibility would vary with the spatial position of the villages, case studies were conducted in five districts namely Alwar, Jhunjhunu, Tonk, Bikaner and Churu of Rajasthan, India, having different population densities.

The outcome of this method is expected to help the policy makers in ranking the districts and blocks in terms of accessibility levels and accordingly allocate funds for the uniform development of the state. From the impact analysis using PMGSY definition, it has been observed that there is a notable improvement in accessibility in all the districts but was higher in densely populated districts.

Accessibility of a habitation to each facility differs in the rural areas. Considering the fact that the Government of India has given tremendous importance on the health sector in the recent times, access to health care has been considered for detailed analysis in this study. Most of the rural population in India are from the low-income group and cannot afford private health centers, thus it has been decided in this study to find access to the Community Health Centre (CHC) which is the first referral unit (FRU) of the rural health care system, as well as a specialist health care to the rural population.

For the purpose of effective healthcare resource planning, a technique named two-step floating catchment area (2SFCA) method has been successfully used over a decade to find access to health care in different parts of the world. This method was later modified by various researchers to overcome its limitation as it uses only demand and supply for quantifying accessibility. One of major and important modification to 2SFCA method was made by introducing a distance decay function and the method has been named as enhanced two-step floating catchment area (E2SFCA). Keeping in view the limitations and gaps in the previous studies, in this study a methodology named modified two-step floating catchment area Method (M2SFCA) has been developed to quantify access to community health center (CHC).

Case studies were conducted in five districts namely Alwar, Jhunjhunu, Tonk, Bikaner and Churu of Rajasthan, India. Initially accessibility of all the habitations in all the five districts were measured using both 2SFCA methods. Then travel friction (i.e., weights for each habitation based on their distance traveled) has been calibrated in all the five districts using the function fitted between frequency of travel of villagers to CHC and the distance of travel. Accessibility was also calculated using E2SFCA method and by M2SFCA method. To quantify accessibility at village level, a village level participatory survey was conducted. In this study to find aggregated perception of the villagers on the quality of the health service provided at CHC and also to find mobility of the villagers, fuzzy aggregation method has been used as parameters or indicators considered were linguistic in nature. The weightages on the importance of the parameters considered for the study were also found through questionnaire survey. Geographic Information System (GIS), MS Excel, SPSS, CurveExpert Professional and MATLAB were used to execute the methods. The accessibility values were found separately for female and males as their perception on the CHC quality of service was found to vary. Further accessibility of the habitations has been found for all the frequently used modes to reach the CHCs such as walk, bicycle, bus, motorized three and four wheelers.

To verify the accuracy of the accessibility values obtained using three methods, a survey was conducted by asking habitants about their satisfaction on the present accessibility level to CHC. Finally, predicted or calculated accessibility values from the three methods were compared with the observed accessibility values. To check the statistical validity paired sample t-test has been conducted. And mean absolute percentage error (MAPE) was also calculated to measure accuracy of the methods. From the results it has been observed that 2SFCA and E2SFCA method failed to predict the true accessibility values of the habitants. Whereas the predicted accessibility values from M2SFCA method significantly represent the actual accessibility of the villagers in all the districts.

The outcome of the study helps the policy makers to identify the habitations not having access to health care and also to know the level of accessibility of the villages having access to health care. This will help to take appropriate measures in terms of improving road network and construction of new health care centers to improve the overall health care facilities in the district.

In addition to quantifying the present accessibility levels, a proper network level planning for road connectivity can boost the accessibility of the rural population to basic needs and can optimize the overall investments. Thus, in this study a need-based approach for rural connectivity was developed using GIS which would ensure accessibility to the basic facilities. The analysis has been done with the map of the year 2000 as the base as the PMGSY program was non-existent at that time. A network was developed using need-based approach to it. Similarly, using the PMGSY approach of population-based connectivity network was prepared. Then both the networks were compared to find the effectiveness in terms of accessibility. To optimize overall cost, the study has also suggested a method to decide the kind of road pavement to be provided in each link depending on its demand.

Key words: *Rural Accessibility Index, Two step floating catchment area method (2SFCA), Healthcare, Impedance function, Fuzzy logic, Mobility, Quality of health care service, PMGSY, Need based network.*

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Symbols

A_i	Accessibility of the population at a given location i to health care
CHC	Community Health center
d_0	Threshold distance
d_m	Maximum threshold travel distance
F	Females
$f(d_{ij})$	Weights from Impedance function
Fj	Weightage for traveling on Unpaved road to reach health center j
HC	Health center
HQ	Head Quarters
HS	High School
HSR_j	Health care standard rating of health center j
M	Males
MDR	Major District Roads
MS	Middle School
O	Observed Values
ODR	Other District Roads
P	Predicted Values
PS	Primary School
Q_j	Quality of service provided by the health center j
RAI	Rural Accessibility Index
R_j	Health care to population ratio at location j
SH	State Highway
TFN	Triangular Fuzzy Number
V_j	Perception of villagers on health center j
%D	Percentage Deviation

List of Abbreviations

Abbreviations	Description
2SFCA	Two-step floating catchment area method
3SFCA	Three-step floating catchment area
ADB	Asian Development Bank
AI	Accessibility Indicators
AIS	Accessibility Indicator Score
AIW	Accessibility Indicator weight
BCR	Benefit-Cost Ratio
CPT	Chinese Postman Tour
CRM	Centre for Rural Management
DHHS	US Department of Health and Human Services
E2SFCA	Enhanced two step floating catchment area method
EIRR	Internal Rate of Return
FCA	Floating catchment area
FGD	Focused Group Discussion
FMCDM	Fuzzy Multi-Criteria Decision Making
FTE	Full-Time Equivalent
GIS	Geographical information system
HH	Households
IDA	International Development Association
IFPRI	International Food Policy Research Institute
ILO	International Labor Organization
IPHS	Indian Public Health Service

Abbreviations	Description
IRAP	Integrated Rural Accessibility Planning
IRAP	Integrated Rural Accessibility Planning
M2SFCA	Modified two-step Floating catchment area Method
MAPE	Mean Absolute Percentage Error
NGO	Non-Government Organization
NPV	Net Present Value
NRHM	National Rural Health Mission
NRRDA	National Rural Roads Development Agency
OTP	Optimal Traversal Plan
PMGSY	Pradhan Mantri Gram Sadak Yojana
RAI	Rural Access Index
SPSS	Statistical Package for the Social Sciences
TCRA	Traffic-Calmed Rural Area

Chapter 1

Introduction

1.1. Background

Physical isolation is a strong contributor to poverty. Problems are severe when a village is located far away from a road and the transport services are not available in time. Roughly half of the world population and 70 percent in the International Development Association (IDA) countries are rural dwellers (World Bank report 2005). A large majority of these people are poor and in the absence of proper accessibility. They spend a significant amount of time in travelling to meet their basic needs of their livelihood. Studies in two areas in Tanzania revealed that on an average 40 to 50 hours of total weekly time available to each household were spent on transport (World Bank report 2003). Thus, there is a need to improve the accessibility in rural areas.

In developing countries, the funds required for enhancing access of rural dwellers, exceeds the available resources. Countries having less population are able to meet these challenges by marshalling internal resources. However, most of the other nations, including India are still trying to meet the minimum access needs of the rural poor. Therefore, there is a need to utilize the available resources prudently and equitably by measuring the present accessibility levels and then take development decision accordingly.

Quantifying access can help the decision makers or the policy makers to prioritize the regions or habitations on the basis of the levels of accessibility. A few methods are available to measure accessibility, in rural areas, but none of them includes all the mobility factors, demand-supply pattern, travel friction and quality of supply.

Accessibility may be defined at different levels – regional and habitational. The regional accessibility measure provides a broad understanding about overall level of accessibility in different countries, states, districts and blocks. The habitational level accessibility measure gives accessibility levels of each habitation to different sectors. They reflect the problems faced by the villagers in accessing the basic or economic needs. Quantifying accessibility at both the levels are useful for an administrator or a decision maker while taking development decisions.

Keeping in view the fact that road connectivity is a prime contributor to enhancing quality of rural life, initiatives have been taken in India to improve accessibility in rural areas. In the year 2000, it was observed that about 40 percent of the habitations in the country were not connected by all-weather roads even though efforts had been made at the state government level over a period of time. Moreover a large majority of the rural roads were not in good condition due to the poor quality of construction and maintenance (Sarkar et al., 2007). With a view to improve road connectivity in rural areas, Government of India launched the Pradhan Mantri Gram Sadak Yojana (PMGSY) in the year 2000. In addition to the budgetary support from the government of India, the programme is also receiving funding from multi-lateral international agencies such as the World Bank and the Asian Development Bank (ADB). The programme was started with a goal to provide connectivity by all-weather roads (single lane width 3.75m) to all the habitations having population of 1000 and above in the plains (500 and above in hilly, desert and tribal areas) by the end of the year 2003. And then was to provide connectivity to the habitation of a population of 500 and above in the plains (250 and above in hilly, desert and tribal areas) by the end of the year 2007. Only new connectivity was provided for habitations, which were unconnected. Out of the total habitations eligible for connectivity 51% of them have been connected by March 2013. Some of the PMGSY roads constructed in the first phase are more than twelve years old now. Even though the roads were maintained by the concerned contractors for the first five years, it is well known that the functional condition of pavement deteriorates due to increase in repeated loads of the vehicular traffic and other environmental factors. It was also observed that in some of the stretches, traffic had increased for too high from projected value. This necessitated the upgradation of some stretches of rural roads by widening the pavement width to 5.5 m and strengthening the pavements. This new intervention has been named as PMGSY- II scheme. The states which have completed the construction of roads under PMGSY- I are only eligible for funding for the implementation of PMGSY-II. A quantification technique has been developed to determine the need for upgradation of links. Even though it is widely acknowledged in general that the construction of PMGSY roads has improved accessibility in rural areas, not much work has been reported on the quantification of the accessibility and assessment of impacts.

The International Development Association (IDA) is the part of the World Bank that helps the poorest countries of the world to reduce poverty by providing interest-free loans and grants for programs aimed at boosting economic growth and improving living conditions. The World Bank has identified 14 performance indicators to evaluate the effectiveness of the lending program both across and within the countries. One of the indicators related to rural roads is the Rural Access Index (RAI) and is defined by IDA as the proportion of rural population with access to all-weather roads within 2 km. However, as per the PMGSY guidelines, a habitation is considered to have connectivity, if there is an existing all weather road within 500 meters of the habitation (in case of Hill area the path distance is 1.5 km). Thus, there is a difference between the distance as suggested by IDA and the PMGSY guidelines. These indicators measure accessibility at a regional level provides a broad understanding of overall accessibility of the entire county, state or a region.

Connecting a habitation by all-weather road or access to all-weather road does not ensure access of the village to basic amenities. From the literature, it is also observed that the construction of roads does not necessarily ensure accessibility and poverty alleviations as the socioeconomic backgrounds of the people are different (Hajj and Setty 2000; Mohapatra and Chandrasekhar 2007; Sarkar et al. 2007). Moreover, accessibility of a habitation to each facility differs. Therefore, there is a need to develop a methodology to find accessibility of a habitation to specific sectors. Integrated Rural Accessibility Planning (IRAP) defines travel needs of rural communities at three different levels based on the purpose (Donnges 1998). The first and foremost is the travel allied with basic needs for the livelihood of rural communities such as water, food and firewood. Secondly, travel related to welfare needs like health and education. Finally, travel related to economic aspects of the rural life, such as market, agriculture, livestock and a small-scale industry. The travel needs to serve economic, social and subsistence purposes depend on the level of mobility as well as sitting and quality of facilities (Dar and Mhina 1997; Donnges 1998; Wilkinson P, et al., 1998; Sarkar and Ghosh 2000; Albert et al. 2000). With respect to the travel related to economic aspects of the rural life, agriculture is the main source of income and employment for the rural people and to access the farm they usually do not travel far, as they are normally located within the acceptable distance. In most of the habitations in India, the basic facilities such as water, food and firewood, are available within a reasonable distance. Also, as per the Indian government policy, primary education is necessarily provided in all the habitations having a population over 500, ensuring the access of the students to elementary education. In the recent times, the private schools have come up in interior rural areas and a large number of parents are sending their wards to these schools. Besides education, another critical welfare need which rural individuals need is access to the health sector. As per 2013 statistics, 60 percent of the population of India does not have proper access to basic medicines and health facilities. Most of the villages are accessible to the nearest primary health center within 8km but due to lack of physicians and medical treatment facilities, quite often the villagers go to CHCs where better facilities are usually available. Although education is also important welfare need in this study health sector has been chosen considering the fact that the Government of India (National Rural Health Mission) has given tremendous importance on the health sector in the recent times.

1.2. Access to Healthcare

Access to health care is considered as a crucial developer of health of the total population (Guagliardo 2004). Quick reach for the primary care can prevent or lessen unneeded costly specialty care (Lee 1995, Luo 2004). Keeping the facts in mind, i.e., to enhance the health of Indian villagers, the National Rural Health Mission (NRHM) of India as per the 12th Plan document of the Planning Commission aims to provide impelling health care to the rural population, especially in the remote and most disadvantaged groups. This goal is proposed to be reached by various methods such as improving access, enabling community ownership and demand for services, strengthening public health systems for efficient service delivery, enhancing equity and accountability and promoting decentralization. Despite the fact that a considerable measure of arrangements and projects are being controlled by the Government yet the achievement and viability of these projects is questionable because of gaps in reaching the rural population. Therefore, in order to assure access to health care, the policy decision makers require definite and reliable measures of accessibility values, so that appropriate health care shortage areas can be identified and policy decisions can be taken accordingly to alleviate the problem.

In Indian rural health care system, the Sub-Centre is the most peripheral and first contact point between the primary health care system and the community health care system.

Sub center is available within the reach of most of the villages. But due to limited and low quality of health care services in sub-center and primary health care center, a large number of people in India turn to the community health center or a local private health services as their first choice of health care. Most of the rural population in India are from the low-income group and it is difficult for them to afford private health care services. So most of the rural individuals travel to community health care to meet their health needs. The community health centre (CHC) is the first referral unit (FRU) of the rural health care system with specialized services. However, studies show that to access CHC about 31% of the population in India need to travel more than 30 km (Gramvaani report 2013). The distance varies based on the population density in the region, number of CHC available and the difference in the quality of service provided by each CHC.

Accessibility to health care often refers to spatial or physical accessibility and is concerned with the complex relationship between the spatial separation of the population and the supply of health care facilities. It is influenced by both spatial factors (geographical location and travel distance) and non-spatial parameters (socioeconomic status, population's health status, financial status, perception about health and the health care system and traditional customs (Day and Andersen, 1974; khan 1992). Many researchers have used different types of methods starting from the spatial time measures by Hägerstrand (1970) to utility based measures by Handy and Niemeier (1997) to quantify accessibility. But the most proven appropriate techniques to measure accessibility are Gravity models which use factor interaction between supply and demand located in different regions with distance decay for addressing the problem of the regional accessibility approach (Guagliardo 2004; Yang et al. 2006). However, the iteration procedures of gravity model are cumbersome, time taking and the results are not easy to interpret. This emerged in development of a new technique named two-step floating catchment area (2SFCA) method. This is a special case of gravity model and has been successful for a decade to find access to health care in different parts of the world (Guagliardo 2004; Wang et al. 2008). It not only has most of the benefits of a gravity model, but is also easy to use, interpret and understand. Two-step floating catchment area method (2SFCA) first proposed by Radke and Mu (2000) but later modified by Luo and Wang (2003a, b) used supply and demand to find accessibility. The application of 2SFCA method has mostly been confined to urban areas, but in this study it was applied to rural areas to determine accessibility to CHC. It was observed that there was no method available that takes demand-supply, travel friction, quality of service and mobility together for quantifying access to health, which are governing factors in rural areas. Thus, the need was felt to develop a methodology which considers all the important factors which constitute accessibility levels to facilities in rural areas. Additionally, it needed to identify health care deficient areas so as to take remedial measures.

In addition to quantifying the present accessibility levels, a proper network level planning for road connectivity can boost the accessibility of the rural population to basic needs and can optimize the overall investments. The perspective of rural transportation planning in developing countries has changed from a 'road-and-car' approach to a 'needs-led' approach (Howe 1998). However, there is a lack of basic understanding of defining the actual role of rural roads in the overall road network hierarchy in developing countries (Hine 1982). In India, there are about 0.6 million villages and many of them have very small population. The demand pattern in rural areas being quite low, connecting villages based on population isolates habitations with less population and in the long run they are deprived of economic and social development. Hence, demand-based approach of connecting villages may not be appropriate; rather a need-based network approach, providing accessibility to all the villages to basic facilities would be more appropriate. The Rural Roads Development Plan: Vision 2025 has also suggested the development of network-based approach for connecting habitations with small population (MORD 2007). Building need-based network for providing accessibility to facilities could be effective in increasing economic potential, efficiency and making sustainable transport links. Thus, it has been felt necessary to develop a need based approach for road connectivity for improving access to all basic facilities.

1.3. Objectives of the Present Study

This study intends to develop methodologies to quantify accessibilities at regional level to all-weather roads and at a habitational level to health care by which inaccessible areas can be identified and appropriate measures can be taken. The rural people need to travel to various facilities to meet their needs and health care is only one of them. Considering the present PMGSY approach of providing connectivity based on population, many of the villages having a low population may not be eligible for connection at all. Thus a different approach is required for such villages for connectivity. Therefore, it has been decided to develop a need-based approach for connecting these villages. Accordingly the following study objectives have been set for this study:

- To find overall accessibility at district and block levels and also to determine the impact of construction of all-weather roads on accessibility.
- Apply a few selected existing methods for the determination of accessibility to health care at the habitational level and then to develop a method that would include all the important parameters that influence accessibility of rural individuals.
- To develop a relationship between travel distance and the number of patients visiting CHCs to determine the travel pattern.
- Develop a need-based approach for rural road network planning to improve access to basic needs and also to develop a methodology to prioritize the construction of the links and also to suggest the kind of pavements to be provided.

1.4. Scope of the Present Study

To apply the techniques for the determination of accessibility in rural areas, it was decided to take up case studies for validation. The present study is limited to a few selected districts namely Alwar, Jhunjhunu, Tonk, Churu and Bikaner in the state of Rajasthan. Accessibility at district levels were determined using IDA and PMGSY guidelines and compared. The impact of the construction of PMGSY roads on the overall accessibility of the concerned districts was also determined.

To determine the village-level accessibility, it was decided to concentrate only on the health sector. Detailed primary and secondary data were collected in a few selected blocks in each of the five districts selected for the study. Data was collected from males and females separately as it was felt that the perception regarding accessibility might vary with gender.

While working on the quantification of accessibility to health facilities, it was felt that road networks play a major role in its determination. Thus a need-based approach rather than a demand-based has been proposed in this study. It has been applied in Tonk district of Rajasthan and a comparison has been made on the impact of such network with

PMGSY approach. Since the demand among links vary considerably, a method has also been proposed to decide about the kind of pavements required at different demand volumes.

1.5. Organization of the Thesis

- The first chapter of the thesis establishes the background and the need for the research activity along with the list of objectives, scope and the details of the thesis organization.
- Summary of the literature review with regard to quantifying accessibility at the regional level, impact of construction of all-weather roads on rural accessibility, quantifying access to health care and calibration of travel friction factor are presented in the second chapter of the thesis.
- The steps followed in the present study is explained in the Third Chapter of the thesis. The steps followed are briefly discussed in this chapter.
- The fourth chapter of thesis deals with the details of the field studies and data collection. The details regarding the selection of study areas, collection of data on various parameters in the selected habitations and health centers have been included in this chapter.
- The fifth chapter of the thesis deals with quantification of accessibility at regional level and impact of construction of all-weather roads on accessibility. It also includes preliminary data analysis and the results of quantified accessibility levels, block-wise and district-wise. The execution using GIS environment has also been illustrated through suitable figures.
- Quantification of accessibility to health care, data analysis and its validation is dealt in the Sixth Chapter of the thesis. Execution of the method developed is presented with appropriate tables and figures.
- The penultimate chapter explains the development of need based technique for rural connectivity. It also deals with the optimal utilization of budgetary resources.
- The last chapter of the thesis concludes the study with findings, conclusions, and scope for further research.

Chapter 2

Literature Review

2.1. Background

A young woman from Little Bay, Jamaica has stated that "If we get the road, we would get everything else, community center, employment, post-office, telephone". A poor man from, Juncal, Ecuador has said that "community without roads does not have a way out". (Narayan et al., 2000). The benefits of connecting villages with a proper road network are extensive and profitable. The importance of rural connectivity has expansively increased in past few decades. Therefore keeping the facts in view throughout the world a lot of initiatives have been taken up by different agencies such as the World Bank, Asian Development Bank (ADB), International Labour Organisation (ILO), International Development Association (IDA), Department of International Development (DFID) and so on. All the investments in rural connectivity has yielded to socio-economic benefits such as decline in prices of agricultural and consumer products, access to education, public healthcare facilities, markets, public transport, employment opportunities and so on (World Bank, 2011). In the 12th five year plan of the Government of India (2012-17), the importance of rural connectivity has been highlighted as a key component in the socioeconomic development of the people. If the linkage is provided to the remote villages they get access to essential livelihood facilities like health, education, marketing, etc. The rural road investments have experienced a substantial reduction in rural people's poverty levels (MORD, 2012). In general, it is very much recognized that the rural connectivity has enhanced the versatility of rural individuals and has given access to markets, which expanded homestead and family unit wages and raised the supply costs for ranch items (Barwell 1996; MORD, 2012). A study by International Food Policy Research Institute (IFPRI) in India has concluded that road investments have reduced rural poverty to a significant extent when compared to investments in agricultural research, development, and education (Mohapatra and Chandrasekhar, 2007). The travel needs to serve monetary, social and subsistence purposes depend upon the level of mobility and in addition sitting and standard of facilities (Dar and Mhina, 1997; Sarkar and Ghosh, 2000; Sarkar, 2002; Donnges, 1998; Wilkinson et al., 1998; Albert et al., 2000). The World Bank at macroscopic scale has demonstrated that access to the basic and welfare needs such as safe water, power and the road network is connected with national per capita income. A study in China has shown that when compared to expressways, the feeder roads and connecting rural areas made a significant commitment to development and poverty decrease, accomplishing around four times more noteworthy benefit to cost proportion (Fan and Chan, 2005). Therefore keeping in view the importance of connectivity of villagers, the present study has aimed at developing a methodology for quantifying present accessibility levels at different levels. And also to develop a need-based approach for connecting a habitation.

One of the objectives of the present study is to determine accessibility at regional level and to find the effectiveness of Pradhan Mantri Gram Sadak Yojana (PMGSY) roads on rural accessibility, hence the background of the studies carried out by various researchers in finding out the impact of PMGSY roads has been viewed. The methodologies used to find the impact has also been reviewed.

It has already been discussed in Chapter 1 that, the main objective of the current study is to develop a methodology to quantify accessibility to health care in rural areas. In almost all the developing countries, including India, funds available for development is a major constraint. So before taking a major decision for development it is important to measure the present accessibility levels to facilities. The techniques used for quantifying accessibility to facilities have been reviewed in detail.

In order to improve the accessibility of the most disadvantaged groups and inaccessible villages, network level planning approaches proposed in the past studies by various researches have been reviewed.

Keeping in view the vast literature available on each of the topics discussed above, and also on the objectives of the study, literature review has been presented in the following three sections.

- Determining accessibility at regional level and find impact of PMGSY roads on overall accessibility.

- Developing a technique to quantify accessibility in terms of travel characteristics and quality of service to the health care facilities.

- Developing a need based approach for connectivity in rural areas.

2.2. Quantification of Accessibility at Regional Level and Assessment of Impact of PMGSY Roads on Rural Accessibility

Accessibility is defined as the ease and comfort with which a person reaches their desired destination. People living in urban areas have easy access to all the amenities when compared to rural areas. As per 2011 census data, 70% of India's population are from rural areas. Hence at international and national levels a lot of initiatives have been taken to improve rural connectivity. Keeping in view the fact that road connectivity is a prime contributor to enhancing quality of rural life, initiatives have been taken in India to improve accessibility in rural areas. In the year 2000, it was observed that about 40 percent of the habitations in the country were not connected by all-weather roads even though efforts were made at the state government level over a period of time. Moreover, a large majority of the rural roads were not in good condition due to the poor quality of construction and maintenance (Sarkar et al., 2007). With a view to improve road connectivity in rural areas, Government of India launched the Pradhan Mantri Gram Sadak Yojana (PMGSY) in the year 2000. In addition to the budgetary support from the government of India, the programme receives funding from multi-lateral international agencies such as the World Bank and the Asian Development Bank (ADB). The programme was started with a goal to provide connectivity by all-weather roads (single lane width 3.75m) to all the habitations having population of 1000 and above in the plains (500 and above in hilly, desert and tribal areas) by the end of the year 2003. And then was to provide connectivity to the habitation of a population of 500 and above in the plains (250 and above in hilly, desert and tribal areas) by the end of the year 2007. Only new connectivity was provided for habitations, which were unconnected. Out of the total habitations eligible for connectivity 51% of them have been connected by March 2013. Some of the PMGSY roads constructed in the first phase are more than twelve years old now. Even though the roads were maintained by the concerned contractors for the first five years, it is well known that the functional condition of pavement deteriorates due to increase in repeated loads of the vehicular traffic and other environmental factors. It was also observed that in some of the stretches, traffic had increased for too high from projected value. This necessitated the upgradation of some stretches of rural roads by widening the pavement width to 5.5 m and strengthening the pavements. This new intervention has been named as PMGSY- II scheme. The states which have completed the construction of roads under PMGSY- I are only eligible for funding for the implementation of PMGSY-II. A quantification technique has been developed to determine the need for upgradation of links. Even though it is widely acknowledged in general that the construction of PMGSY roads has improved accessibility in rural areas, not much work has been reported on the quantification of the accessibility and other impacts.

Many researchers have conducted impact assessment studies to find the effectiveness of the investments in rural development. The World Bank conducted a study from 1987 and 1991 in the Kingdom of Morocco to find the influence of rural roads on socioeconomic parameters of rural people. The study was based on two-types of analysis: first, the current condition of the concerned roads was compared to those before investment and second there was a comparison between the condition of a project road with that of a control road, which did not benefit from improvements over the period of study. Extensive surveys were carried out at farms, regional and habitational levels for the collection of data and with the help of focus group discussions (Levy and Herman,1996).

To evaluate the impact of the road investments and for prioritizing funds the traditional methodologies for transport projects (Road investment decisions) are used, i.e., Net Present Value (NPV), Benefit-Cost Ratio (BCR) and the Internal Rate of Return (EIRR) (Hajj and Setty, 2000). In most of the cases for low volume roads the standard estimates is not able to justify the investments (Parida, 2014).

A study was conducted by the ministry of rural development through different agencies in 2004 to find the overall socioeconomic impact of construction of PMGSY roads on rural development. The study was carried out in 9 different states. A survey was conducted in the villages which were connected by PMGSY road. The perception and responses of the community on indicators were used to analyze and find the impact of PMGSY on sectors such as agriculture, health, employment, education, transport and poverty alleviation. The construction of the PMGSY roads has greatly benefited all the sectors. However the results from the study were limited to the perception of sample respondents. For example, in the study conducted in Chhattisgarh, India in 2009 to find a socioeconomic impact assessment of rural roads, they used the six survey instruments to assess impact of rural roads. The transport-related impacts were assessed using the instruments one and two. The survey instrument concerned with village level data/information were 3, 4 and 5. The monitoring of the sample household levels for any changes was done using instrument 6. The situations were compared between the habitations whose road connectivity had been improved and villages which did not have good road connectivity (TCS, 2009). Two studies were conducted by the Centre for Rural Management (CRM), Kottayam, India for finding out the impact of PMGSY roads in the states of Tamil Nadu and Andhra Pradesh. Focused Group Discussion (FGD) was held by them at habitation level and household levels comprising samples from different backgrounds. They used two approaches 'Before and After' & 'With and Without' approaches which are commonly used in impact assessment studies. It has been reported from the study that PMGSY road has helped people in the rural areas to boost their living conditions (Jos, 2011). However, all these studies have concluded the results directly from the samples obtained through questionnaire surveys. The findings are generalized for the whole state. The impact mentioned merely depends on the perception of the respondents. The reliability of the results directly depends on the number of the respondents participating in the survey. But a huge amount of resources, both time and money, are required to collect a representative sample which may not be feasible in some cases.

The International Development Association (IDA) is part of the World Bank that helps the poorest nations of the world to reduce neediness by giving premium free advances and stipends for projects which aim at boosting monetary development and enhancing living conditions. IDA helps these nations manage the perplexing difficulties they confront in endeavoring to meet the Millennium Development Goals. Interest free and long-term credits pay are provided by IDA for projects that construct the strategies, organizations, foundation and human capital required for impartial and ecologically supportable advancement. IDA's objective is to lessen disparities both crosswise over and inside nations by permitting more individuals to take part in the standard economy, diminishing destitution and elevating more equivalent access to opportunities made by economic development. The World Bank has come up with 14 IDA indicators in order to monitor and evaluate the viability of any lending system. One of the pointers identified with rural roads is the Rural Access Index (RAI) and is characterized as the extent of rural population with access to all-weather road within 2 km. Although RAI does not reflect the problems faced by the villagers in accessing the basic or economic needs, it measures accessibility at the regional level.

From the literature, it has been observed that IDA indicator, RAI is the best tool to measure the accessibility as the process of measuring is quick and provides a broad understanding of overall accessibility of the entire county, state or a region. Hence, in this study IDA indicator was used for measuring accessibility at regional level. The indices were also determined as per Pradhan Mantri Gram Sadak Yojana (PMGSY) definition of accessibility. Also, using IDA and PMGSY definition, the effectiveness of the new road construction on accessibility is measured.

2.3. Quantifying Accessibility to Health Care at Habitational Level

For quantifying accessibility many methods have been developed throughout the world. The most frequently used methods for finding accessibility are discussed in detail.

Place accessibility

Land utilization patterns and transportation elements are normally utilized to infer Place accessibility (Handy and Niemeier, 1997; Kwan, 1998). Land patterns refer to the location of various activity destinations, spatial dispersion of the destinations and extent, standard and character of the administrations delivered there. The transportation system includes the separation, the aggregate travel time and the expense of travel by distinctive modes of travel (Handy and Niemeier, 1997). It is possibly operationalized in different methods relying upon the current issue (Handy and Niemeier, 1997; Ingram, 1971). Integral measures, utility-based measures and gravity-type measures are generally used to quantify place accessibility. Regardless of method of measure chosen, it has to be aligned to reflect the people and households' view on travel and destination decisions (Handy and Niemeier, 1997).

Distance measures

An easier and direct measure of accessibility is the Distance measures as it measures distance as average distance, minimum distance or weighted area distance. These distances are assessed in different methods, for example, simple straight-line distance to complex impedance definitions. The lesser the distance the higher is the accessibility. The fundamental presumption is that all activities are situated in the destination range or that the dwellers just esteem access to these activities (Song, 1996). Another easy distance measure is the maximum value obtained from a single location, this is utilized when there is no compelling reason to pick between areas. The attraction associated with a particular destination is not included in the average and straight distance measures. However, the weighted average distance includes the attractiveness of the destination.

Utility-based measures

Random utility theory with the denominator of the multinomial logit model (logsum) is used in Utility-based measures (Handy and Niemeier, 1997; Sonesson, 1998). The hypothesis is in light of the supposition people have a tendency to amplify their utility. This means each destination is given a utility value by the individual and the probability that an individual will pick a specific destination relies on the utility of that destination contrasted with the utility of the considerable number of others (Sonesson, 1998). The utility capacity comprises of variables which speak to the traits of every decision, the degree of attractiveness of a specific destination, travel impedance, and the financial attributes of an individual or family unit. A benefit of this measure is, it empowers experimenting with different utility function formulations, hence the function which best matches the original travel behavior is formulated using this method.

Individual accessibility measures

Individual accessibility quantifies accessibility with regard to a specific individual distinct needs, particular mobility, fiscal and time assets. Kwan (1998) and Pirie (1979) depict the individuals' encounters on the accessibility and furthermore assume that all people in one zone don't have the same accessibility levels. Besides, they consider the way that the greater part of travel trips made by an individual is in the setting of a day by day routine taken up by the person. Thirdly, this measure reflects the spatial-temporal constraints which can create opportunities in the urban habitat that cannot be reached by an individual.

Space-time measures

The hypothesis of space-time measures were initially presented by Hägerstran (1970). The volumes of the space-time prism are used in these measures as an indicator to exhibit the feasibility of chances to an individual while quantifying accessibility. Hägerstrand for the most part spotlights on characterizing the time-space mechanics of requirements and recognizes three interdependent aggregations of limitation. The three constraints are capability constraints (a function of time or distance), coupling constraints (function of coupling or activity time) and authority constraints (control area or domain). Usually in all the space-time measures they try to replicate a singular's conceivable conduct, not his likely future.

Kwan (1998) built up a distance network matrix for all areas utilizing the shortest path algorithm to make the space-time measures operational. A noteworthy issue with this measures is that they rely on the data of finished exercises and travel trips. This dependency on large amounts of information about completed activities and trips one makes is difficult to use in space-time measures in large-scale projects. Notwithstanding, by fusing the impact of space-time limitation enhances the capacity to clarify and foresee the qualities of an individual’s travel behavior.

Gravity measures

Hanson (1959) first introduced Gravity-based measures. These measures are obtained from the fraction of gravity model for trip distribution. Exponential form of gravity model was used as supported by statistical theories. They are derived by giving weights to the chances in a territory alongside a measure showing their origin and destination attraction (Geertman and Ritsema van Eck, 1995; Kwan, 1998; Handy and Niemeier, 1997; Sonesson, 1998). The relative accessibility in a particular location is defined as the attraction at the destination and distance between the origin-destination (supply-demand) points marked down by the impedance function. The most commonly used distance decay function is the inverse power function and negative exponential. (Weibull, 1976; Joseph and Bantock 1982; Joseph and Phillips, 1984; Shen, 1998; Huff, 2000; Wang and Minor 2002; Guagliardo 2004; Yang et al., 2006)

Floating catchment areas

Floating catchment area (FCA) method quantifies spatial access to services by utilizing population-to-provider ratios. Guagliardo (2004) has distributed complex measures of spatial accessibility to medical care which are ordered into four classifications: supplier to-population proportions, distance to closest supplier, normal distance to an arrangement of suppliers and gravitational models of supplier impact. This strategy is utilized for circular buffers around the population centroids keeping in mind the end goal to figure a supplier to-population proportion of the quantity of encased facilities. Just supply is considered in FCA technique ignoring demand, which stays as a noteworthy setback of this method.

Two-step floating catchment area method (2SFCA)

Radke and Mu (2000) has overcome the limitation of FCA method by solving supply-demand issue by building up a spatial decay system which Luo and Wang further explained and alluded to as the two-step floating catchment area (2SFCA) method (Luo and Wang, (2003a); Luo and Wang, (2003b); Wang and Luo, 2005; Langford and Higgs 2006; Luo and Yi; 2009). 2SFCA strategy is an exceptional instance of gravity model and in addition utilizes basically a unique type of physician-to-population ratio. The method is executed in two steps. In the first step for each physician location, all population locations within a threshold travel time or distance are searched for and the physician to population ratio is calculated. In Second step, for each population location, all physician locations are searched for within the threshold travel time or distance and their respective physician-to-population ratios, calculated in the first step are summed up. The major confinements of 2SFCA technique are, all locations outside of the catchment have no access at all and all population locations within the catchment are accepted to have equivalent access to physicians (Wan, Neng et al., 2012; Neutens and Tijs, 2015).

Enhanced two-step floating catchment area

Luo (2009) worked on the limitations of FCA and 2SFCA methods and derived enhanced two-step floating catchment area (E2SFCA). In this the 2SFCA method has been enhanced by differentiating accessibility within a catchment by incorporating multiple travel time zones and giving weights according to decay function within each catchment. The limitation of this method is, it did not consider the quality aspects.

Optimizing the two-step floating catchment area method

Ngui et al., (2011) used the shortest network distance and computed catchments around existing medical clinics. The optimization of 2SFCA method is done by giving weights to medical clinics (supply) on the premise of the quantity of doctors working in every facility, and medicinal facility clients for the earlier years were utilized as a weighting coefficient for potential clients. However the travel characteristics were not considered in this method (Wang, 2012).

Three-step floating catchment area

For an effective planning, a three-step floating catchment area (3SFCA) method is proposed. The foremost of this method is to minimize the over-estimation in healthcare-demand. The model is in light of the supposition that a population's interest for medicinal administrations is administered by the availability of other nearby medical sites. For every pair of existing population-medical sites weights are appointed based on the travel time and further weights are utilized in the calculation of the demand of services site (Wan et al, 2012[a]; Wan et al, 2012[b]).

The major advantage of the 3SFCA method over previous models is that it minimizes the overestimation problem by incorporating travel-time-based competition scheme for medical sites which uncovers lower demand.

There are several issues that require special attention while implementing the 3SFCA such as the determination of the catchment size. The catchment size could vary as per neighborhood qualities and the specific sort of medical service in demand (Yang D.H et al., 2006; Mc Grail et al., 2009[a]; Mc Grail et al., 2009[b]; Mc Grail et al., 2009[c]).

Integrated Rural Accessibility Planning (IRAP)

IRAP is a planning tool that is participatory and bottom-up approach. It is an integrated methodology for a rural local level planning to fulfil their needs by making them connected to multiple sectors. Many methods have been developed around the world, to quantify the accessibility to various essential sectors like drinking water, primary education, health facilities etc. IRAP rose out to be a persistent procedure of approach advancement, which has been attempted subsequent to the 1980's in various nations, for example, Tanzania, Philippines, Bangladesh, Malawi, India, Nepal and Zimbabwe. (Affum et al.,1995; Barwell and Jonathan,1993; Connerly and Larry, 1996; Edmonds et al., 1994; Howe,1983; Ahmed et al., 1995; Sieber,1996; Ali-Nejadfard, 1997; ILO-ASIST AP, 2003; Donnges et al., 2004; Sarkar, 2005; Sarkar and Ghosh, 2008). All these methods are scrutinized as discussed below.

(i) Method developed for South Africa:

The method was developed with an objective of identifying travel-based exercises and their significance to the individuals in rural regions and added to a technique for measuring and organize the accessibility of different rural ranges. Overall accessibility of rural areas is the cumulative aggregation of the product of weights and present satisfaction level of accessibility to the respective activity. Through this method reasons for lack of accessibility and their exact contribution to the problem are not known and thus, the overall accessibility levels do not help in the decision making process. The exact problems (like lack of road network, poor quality of the service, etc.) are not reflected by this study. The population of a locality is not considered while deciding the fund allotment among the various villages which is illogical. In this case even a village with larger population might not be improved when compared to a village that is sparsely populated.

(ii) Method developed for Malawi and Tanzania:

Accessibility Indicators (AI) are critically used which show relative degrees of trouble in getting facilities and services. AI also measures the demand size of the households and the level of their mobility in a given region. The number of households was considered in this method which partially reflects the effect of the problem on the economy of the village. This factor would consider the total effect of the problem on the community instead of a single individual. It involves very less inputs and thus makes computation easier. As AI is individually computed for every sector without any rationalization (ranking) comparison of the final indexes would be incorrect. The importance given by the people to the sector is not taken into consideration which results in some values that might not reflect the actual needs of the people. Reasons for lack of accessibility and their exact contribution to the problem is not known. AI does not help in the decision making process as the exact problem (like lack of road network, poor quality of the service, etc.) is not reflected in the study.

(iii) Method developed for Orissa:

The accessibility indicators are subjective and quantitative appraisals of distinctive circumstances. The indicators are a component of variables, for example, the number of families in the town, the normal time spent to reach every sector and chose subjective qualities. These indicators are used to rank the villages.

AI is a component of population, travel time and quality elements. The formula may vary for diverse facilities. A multi-criteria scoring framework has been utilized to compute AI. This method accounts for the issues of a region all the more precisely and definitively. As the commitment of different elements to a specific issue is mulled over, the distribution of funds can be done based on the indexes. Factors like population and quality factors help to understand and solve the problem more effectively. However, the priorities of the local people are not included in the computation of the accessibility index. So sector with highest index might not be the actual need of the local people.

(iv) Method developed for Rajasthan:

To alter the habitats' need, indices were created to measure the current levels of accessibility in each habitation. The elements considered for evaluation are population variables represented by the number of families in the habitation, time element, and quality element. Each of the mentioned factors has quantifications in terms of the score and the weights assigned to each of these parameters based on their significance to the access problem. The scores were doled out to be chosen in counsel with the nearby government authorities and the village agents of the considerable number of village in the study territory. They are subjective in nature, yet mirror the view of the nearby group into the accessibility issues confronted by them.

In a given sector the village with the greatest priority index is considered. For this village representatives in collaboration with the local government representatives brainstorm the conceivable intercessions to enhance the access in the needy villages. The priority index is computed for each solution. Priority for different sectors and the satisfaction level of the local people give an abstract view of the accessibility in that sector. The various sub-factors (like teacher score, classroom score, student to teacher ratio score and student to classroom ratio score in quality factor for education sector) that determine the contribution of a factor to a sector are not considered. A weight is assigned even to population factor in each sector which holds very less meaning. Adding the population factor might not be correct. The inconvenience in the case of time spent in travel and the standard of the service would become equally crucial for every person accessing the facility. The weights are determined by consulting the representatives of each village. But, an average of the weights of all the villages is taken. This might aggravate the actual problem or even attenuate the problem in case of some villages. So, the final index might not help in identifying the problem area accurately.

(v) Method developed for Nepal

In this case Accessibility Index (AI) is calculated based on various criteria. Generally AI calculated along certain lines need not be logical for all the sectors. For example, a sector like irrigation need not consider the aspect of "average time travel to the service". Only the quality of the service might play an important role.

The Index represents various factors and even sub-factors of each sector, which makes the method most accurate of all. The assignment of weights to the sub-factors help to avoid greater AI for a sector because of a number of sub-factors. The number of inhabitants in the zone is reproduced to the Social Accessibility Index, which reflects the complete effect on the area under consideration. The actual wants of people in a sector are also catered by attaching the weights to each factor.

Both difficulty factor and weight to the travel time are multiplied to the access time score. But, both the factors reflect the priority of the people. So, the score is assigned a weight twice, which might result in biased AI. The total number of households is taken into consideration, whereas the actual affected people might be much lesser than the total population. The quality of the transportation infrastructure to a service was not considered.

(vi) Method developed for Indonesia:

In the method developed for Indonesia, Accessibility Indicator Score (AIS) and Accessibility Indicator Weight (AIW) are computed. AIS is acquired by contrasting the condition of a sector in the village under consideration with the models determined for the sector. The weight to different variables inside of a sector is dictated by including the local individuals. The Accessibility Score represents various sub-factors of each sector. On the other hand, this strategy can't be utilized to look at the accessibility between any two services or sectors. The principle downside of the technique is the reverse result it gives. As the final result is inversely proportional to the population and the severity of the problem (sum of the indicators) the greater the final score the lesser should be the intensity of the problem. But the result is considered in the opposite manner.

All the IRAP methods discussed so far are developed by various nations in order to quantify the needs of the people in the rural area. The main aspects that need to be fulfilled while devising a method are

- The involvement of the local people in computing the index is very important as the final decision taken by the management must cater to the needs of the people using it.

- The computational part of the method should be as simple as possible. Even if the process is lengthy, it should be easily intelligible.

- Accuracy should be given the next priority as an approximation at various points might either exaggerate or attenuate the actual scenario.

- The formula should be devised in such a way that the final index always lies in a certain range. This makes the comparison an easier as well as a more logical task

Miscellaneous methods

The accessibility of a region was described as the aggregation of the shortest path distances (Garrison, 1960). Slowly network analysis became popular and it was timely modified (Armstrong, 1972). Travel time is the easiest measure of accessibility when public transport facilities are available (Forbes, 1964).

Ingram (1971) has explained the concept of accessibility with relative (extent of connectivity between points) and integral accessibility (extent of interconnection with every single other points). At first the attention was on accessibility to zones which was later supplanted by availability focusing on particular capacities or exercises (Breheny, 1974).

Various authors related accessibility with the traffic stream movement as they measured the distance components in accordance with the observed stream or flow pattern (Savigear, 1967; Dalvi and Martin, 1976).

The Conventional transport strategies overlook the way that perception of individuals on mobility and accessibility broadly differs (Markivitz, 1971). In this manner, transport planning should ought to be gone for fulfilling travel needs (Burkhardt and Eby, 1973). The planning of the Transport network should be done in such a way so that the quality of travel (Stanley, 1975) and public transport functioning could be led at the very least level of administration (Peat and Mitchell, 1977).

East Anglia Study is a valid example for the measure of personal accessibility as the analysis is focused on explaining the general importance of accessibility as activity specific, group specific based on their car ownership and time spent on travel. (Moseley et al., 1977; Nutley, 1989). In totally distinctive methodology the requirements (social, monetary, area utilization, transport) which keep needs from being fulfilled by the overall transportation framework, were distinguished.

A technique was developed by Jordaan and Jordaan in 1992 to quantify accessibility of rural groups to the current road network. Accessibility was defined on the basis of the distance between the nearest gravel or earthen road and surfaced or paved road. In Mokerong II area Northern Province, contour method was used to measure accessibility (Jordaan, 1997).

Accessibility to a service depends on parameters such as separation, travel time, travel cost, responsibility for, availability and standard of public transport, type of road surface and numerous others (Sarkar et al., 2008). Simple techniques for quantification of accessibility such as weighted aggregation method were used. Also other multi-criteria techniques by which the accessibility of each village to facilities evaluated in light of those parameters and existing conditions were applied. To find the effectiveness of construction of roads the comparison was done between connected and unconnected villages. It may be noticed that the levels of accessibility figured utilizing this strategy are not outright values and would just help in looking at the levels among villages.

2.2.1. Observations from Accessibility measures and Research Gap

Accessibility measures are subject to the area utilization and transport models. Accessibility measures don't concentrate on estimating the improvement, but instead on clarifying the effect of diverse urban or local land use frameworks of social and monetary communication (Geertman and Ritsema van Eck, 1995). Accessibility measures using transport models are in fact unrivaled, however, execution of these models is costly and furthermore the outcomes are hard to decipher. Accessibility measures, then again, have the benefit of being effectively deciphered and utilized.

As indicated by Handy and Niemeier (1997) it is conceivable to join measurable parameters with subjective assessments. This aides in a superior comprehension of the accessibility qualities. It needs to be understood that distinctive accessibility measures catch diverse measurements of access, and the decision of strategy influences the last result. The accessibility measures must be picked remembering the presumptions whereupon every method is dependent on (Guy, 1983; Kwan, 1998; Song, 1996). In connection to place accessibility, integral measures showed noteworthy results when compared to other measures and this measures are valuable for looking at accessibility between different regions. Different studies demonstrate that gravity measures give preferable results over cumulative measures. Regional or Zonal accessibility measures do not differentiate access of individuals within the region and consequently are not proper for assessing individual accessibility (Kwan, 1998; Pirie, 1979). A more suitable way to deal with individual accessibility is much of the time to see occupants and opportunities as point patterns. With a specific end goal to conquer the restrictions of integral measures it is important to change space-time arranged measures. Because of the dependency of space-time measures of definite data on finished activities and numerous other difficultly obtained data, this method yet confronting numerous challenges in execution. It likewise must be recalled that space-time measures are difficult to generalize while gravity and aggregate measures produce distinctive spatial patterns of accessibility.

For the purpose of effective healthcare resource planning, two-step floating catchment area (2SFCA) method which is a special case of gravity model has been successful for a decade to find access to health care within different parts of the world. However, this method was later modified by various researchers to overcome its limitation as it uses only demand location and supply location and demand to supply ratio for quantifying accessibility. However the modified methods also do not replicate the true accessibility values of villagers to health as they were all designed for an urban area.

IRAP methods quantify the needs of the people in the rural area. These methods follow specific guidelines in measuring accessibility. Also, all the methods developed by IRAP in different countries use only multi criteria based techniques to measure accessibility.

After reviewing various accessibility measures developed in the past, it has been observed that most of the methods developed are urban specific, and there is no method that takes demand-supply, travel friction, quality of service (attractiveness) and mobility all factors together for quantifying access. So in this study it has been decided to find the true accessibility values of the villagers by considering all the important factors that influence it.

2.4. Calibration of Impedance Function

Tobler (1970) stated that "everything is related to everything else but near things are more related than distant things." But the difficult aspect is to define the shape or form which the decrease in the interaction intensity along the distance takes on. The distance friction parameter is the most vital component of a distance impedance function, it reflects a prominent aspect of spatial behavior – travel threshold (Wang, 2006). In theory the distance friction parameter in gravity models and accessibility modes has always been treated as fixed, but in reality this parameter is dynamic in nature. Travel impedance is measured by distance or time and is calculated by straight-line distance, network distance and field surveys of actual driving time or surveys of residents' perceived distance or travel time (Handy and Niemeier, 1997).

Ideally the weight parameters of travel should be generated from the calibration stage of trip generation models based on observed travel behavior in the study area (Fotheringham and O'Kelly 1989). The physical analogy of inverse square root function or just simple inverse function was applied by Isard (1960) and Haggett (1965). These were later questioned by Wilson (1974), Alonso (1978), Fotheringham and O'Kelly (1989), as just for their simplicity they have insufficiently approximated the reality. Goux (1962) suggested several functions that are able to describe the distance decay in interaction intensities and they were called family of distance decay functions. The issue has been further analyzed and developed by Taylor in 1971 (Taylor, 1983). The correct shape of the distance decay function is important for spatial interaction modelling and the calibration of models which are applied in various geographical milieus including migration, labor commuting, transport, retail behavior, regional taxonomy, etc.

The omission of a distance decay function is proportionate to tolerate that travel distance or time is an important hindrance inside of a catchment. A distance-decay function is pivotal in provincial zones, particularly where there is poor access to medical services. At present there is very little exact confirmation to control the decision of one decay function over another. The original and unmodified 2SFCA method does not differentiate accessibility within the catchment as it utilizes a binary discrete function. In the 'enhanced' 2-step floating catchment area (E2SFCA) method, where catchments are divided into three or more discrete zones based on travel time range with same weightings applied to the accessibility within each zone. The principle downside of the zonal or step function to deal with substantial topographical ranges is that accessibility weightings are equivalent inside of every zone and there is a sudden step (drop) at the edge of every zone (Hansen, 1959; Salze et al., 2009). Numerous researchers have created a distance-decay functions which are smoother and consistent in their fall (Hansen, 1959; Ravenstein, 1885; Echenique et al., 1969; MTARTS, 1966). However, without any empirical evidence, it is unclear which function is the most appropriate to use.

Stewart (1941) noticed that the impact of population between the two places was contrarily corresponding to the separation between them, consequently opposite separation weighting capacity. From that point forward, numerous distance weighting functions have been proposed for spatial interaction models and for potential models.

Decay function or Impedance travel can be seen as people's willingness to travel according to trip purpose, demographic characteristics or destination attractiveness. Inverse power and negative exponential are the most commonly used functions (Salze, 2011). Kwan (1998) identifies the three most frequently used impedance functions for gravity-type accessibility measures:

Inverse power function

$$f(d_{ij}) = d_{ij}^{-\beta}$$

Exponential function

$$f(d_{ij}) = e^{-\beta d_{ij}}$$

Gaussian function

$$f(d_{ij}) = e^{-d_{ij}^2 / \beta}$$

Where β is an empirical parameter that represents distance friction and d_{ij} is the distance between origin, i and destination, j

Guy (1983) and Kwan (1998) found that these distance decay functions decline too steeply close to the trip origin and produce unrealistic accessibility patterns. As shown in Fig.2.1, the Gaussian measure, resembling the bell shape normal distribution curve, drops gradually at first, then more abruptly as the distance increases from origin (McGrail, 2012).

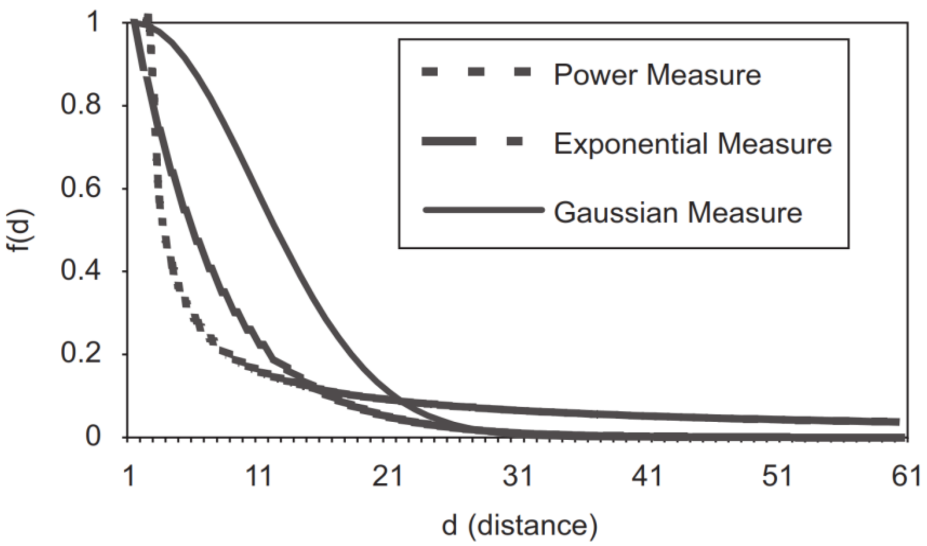


Fig. 2.1. Distribution curve for travel friction

From the literature, it has been observed that most of the studies commonly use inverse power, negative exponential and Gaussian functions. In some studies step functions are also frequently used. But most of the studies did not find the impedance function to calculate distance decay, which could be preferably found from the calibration stage of trip generation models taking into account observed travel behaviour. It might be due to the lack of information on the revealed spatial behaviour of population at different locations. The travel friction or impedance function or distance decay function is region specific and needs to be calibrated from the pattern of interactions. It reflects the travel behavior. However, as stated by Stewart (1941) in this study that distance decay function has to be calibrated from the people's travel behavior.

2.5. Development of Need Based Approach for Rural Road Network Planning

Road construction has always been considered important for rural development, but the rational approach of road construction has changed. In the 1960s and 1970s, roads were seen as an asset in economic growth by connecting areas of potentially profitable agriculture. (Bryceson, 2009; Grieco and Margaret, 2009)

In general the decision of connecting a habitation is based on the demand criterion. In a study conducted by Mineetha (1992), villages were connected based on the trips produced from the village. Three stage rural road network planning has been suggested by Purushottam et al (1993) for rural roads planning in Andhra Pradesh. Transport Priority index, Link Priority index and the Village Affinity index were used for node choice, link choice and network choice. Daya Krishnankutty (1997) also used trip rates for developing road network. The average trips rates of villagers were predicted by developing multiple regression model from the travel characteristics data collected from household surveys. Raji (1997) developed a systematic procedure to identify hierarchy of settlements using non hierarchical clustering.

UNCHS (1985) suggested set of simple evaluation criteria or indicators related to detailed engineering and economy to evaluate the network options. It also proposed indicators based on graph-theoretic measure of connectivity in a network and gravity concept based measure of spatial accessibility. The spatial properties were only considered ignoring the access to facilities.

Mahendru et al. (1982, 1983, 1985, 1988, 1989) proposed an integrated area development approach for developing the rural road network. Level of socio-economic development, population and spatial separation between settlements have been used to quantify interactions between settlements using gravity hypothesis. Link, route and network efficiencies were calculated to evaluate alternative rural road linkage pattern developed. Additionally the total operating and construction cost and total link length were considered to arrive at optimal network (Mahendru et al 1986). The accessibility to the basic facilities was completely ignored while network planning

Jaarsma and Catharinus (1997) introduced a new spatial concept of traffic-calmed rural area (TCRA) for serving both interests of accessibility and sustainable environment. This idea focuses on the current diffused streams on minor rural, which resulted in a decrease of volumes and speeds within a region. A speed limit of 80km/h for major roads and 60kmph for the minor roads was proposed. In light of this system, activity volumes and go times per street connection were figured. Also the impacts of TCRA on accessibility, traffic performance, and safety and habitation fragmentation was analyzed. These impacts were then compared to the autonomous development.

In general shortest path algorithms are used to develop the links. In case of failure to attain the shortest path alternate routing is planned. Alternative routing was studied at the beginning of the 1950's in the context of this a second shortest route was found if the shortest route is blocked. Shortest path algorithms are widely used problem-solving model even today. The research started with Shimbel, 1955 and then followed by Ford, 1956; Leyzorek et al., 1957; Dantzig, 1960; Bellman, 1959; Dijkstra, 1959. In Dijkstra algorithm the shortest path between nodes in a graph is found. It is an iterative algorithm which provides a shortest path from one particular starting node to all the other nodes in the graph. Robert C. Prim and Dijkstra in 1957 rediscovered Prim's algorithm for a weighted undirected graph. It is a greedy algorithm that finds a minimum spanning tree for a weighted undirected graph. The minimum spanning tree concept was used by Swaminathan et al. (1982) for connecting settlements to existing nearby roads or to the nearest market in rural areas, but the network generated was not proved for optimality. Kumar and Tilloston (1989) also used the minimum spanning tree concept for generating an optimum road network by minimizing construction and travel costs of the links. However the approach is not driven by the need-based concept. Rao et al. (2007) proposed GIS based technique in which minimum spanning tree was used for identification of the core network and rural road planning. The efficiency of the core network and meeting access needs of was not explained.

Leyla et al (2007) proposed two algorithms to find the optimal traversal plan (OTP) of a directed road network. The algorithm employs a graph traversal algorithm in which it minimizes total travel time by using a set of heuristics at each intersection. Using an approximate solution the algorithm finds a near optimal answer. It has noted that near-optimal algorithm calculation gives preferred results over prim's algorithm when trailed on real street networks interms of total travel expenditure, while keeping its complexity tolerable in real-world cases.

To ensure minimum connectivity for each village to nearby road or market, Ministry of Rural Development (MORD) in India (MORD 2002) and World Bank (World Bank RT-4 2000) have suggested master planning guidelines for identifying core network.

In the recent years, many researchers have applied Geographical information system (GIS) to solve problems involving rural planning and maintenance (Sidkar et al., 2003; Manyazewal et al., 2014). Kumar et al (2004) has developed a rural road network model based on the facility using GIS. Anjaneyulu et al. (2007) presented a methodology for planning rural roads using GIS and secondary data sources. Functional dependencies of settlement and potential interactions have been used for network planning. The developed network was evaluated using Graph theoretical indices and structural properties of the network. The accessibility needs were not considered in developing the network. Network analysis tool in GIS is successfully used to solve transportation routing problems such as finding the most efficient travel route, generating travel directions, finding the closest facility, defining service areas based on travel time, etc. Abdel and Yehya (2011) used spatial analysis to assess road networks with geographic information system (GIS) in Egypt and concluded that GIS is an important tool for the urban development strategy to facilitate informed decision-making in its planning process. Dixon (2012) has used network analysis to develop a least cost corridor. In his study, habitat preference values are used which are developed from a habitat selection framework using a combination of elephant GPS point locations with a land cover dataset.

Prasada Rao et al, (2003) used GIS for planning rural road connectivity of a community development block and the information system was developed for village and rural roads. Accessibility approach was used for developing the road network. Optimal links have been provided to the villages by maximizing access and minimizing construction cost. Kumar (1997) suggested facility based approach for rural road planning. The road network has been developed by connecting habitations to the nearest market in such a manner that maximizes the number of educational institutions fall along it. However, all the access needs were not considered in developing the network. Singh (2010) in his study also developed rural road network based on accessibility approach and using GIS platform. Road links were evaluated for their efficiency in accessing facilities based on the index developed.

Misra (2008) proposed inter-settlement interaction and functional accessibility approach for rural road network planning. Population size and socio-economic status of habitations have been used to decide the hierarchy of connectivity. An index parameter was developed for the settlements which reflects the importance or deprivation of the habitation and helps in selecting the target habitations for connectivity. For selecting the suitable road link among available link options, which provides connectivity to unconnected settlement, the accessibility benefit concept was used.

In a study conducted in Nepal attempt has been made to develop the rural road network for developing countries by determining obligatory points and maximizing access to basic services using Maximum covering location model (MCLP) (Shrestha et al., 2013).

The principle center of both land use planning and planning of the rural road network is on monetary and social effects. Access of rural habitants to basic facilities was not the prime concern in most of the network plan developed in previous studies. It is also clear from the review of literature that road connection and planning is traditionally based on demand. And shortest path and prim algorithms are used to find the paths using GIS platforms. However, not many research studies have attempted to develop a technique for constructing need-based routes to improve rural accessibility to basic facilities.

Chapter 3

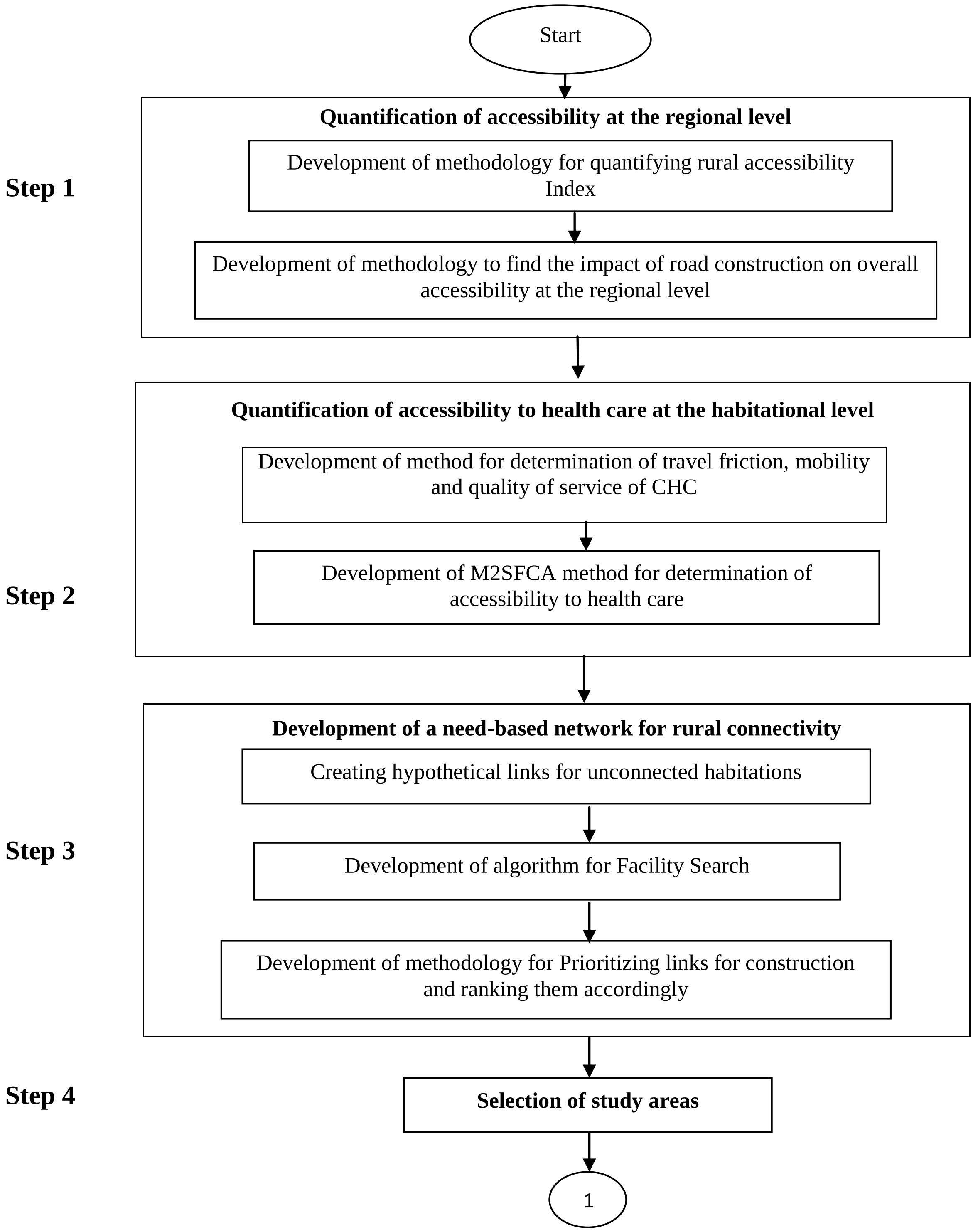
The Steps Followed in the Present Study

3.1. Background

The objective of this study is to develop a methodology to measure accessibility at two different levels - regional and village. The regional accessibility provides a broad understanding about overall accessibility in different countries, states and districts, which help in ranking them in order of accessibility. Whereas habitational level accessibility measure provides accessibility of each habitation to different sectors. Moreover, they reflect the problems faced by the villagers in accessing the basic or economic needs. Quantifying accessibility at both the levels are useful for an administrator or a decision maker while taking development decisions. The methodology proposed in this study primarily follows the existing methods used for measuring accessibility using indicators developed by the International Development Association (IDA) for a regional level measure. A two step floating catchment area method (2SFCA) for a village level accessibility measure. The methods have been applied directly and then necessarily modified and strengthened until they have reflected the ground situation. The Impact of construction of all-weather roads on regional level accessibility have also been measured using method developed for regional level accessibility. This is expected to help in understanding the effectiveness of construction of all-weather roads in different regions with varying characteristics and then to take appropriate decisions for investments within limited budget. Also, keeping in view the fact that proper planning at network level will improve accessibility to basic amenities, a need-based approach for rural road network planning has been developed.

3.2. Steps Followed in the Present Study

The present study has been carried out step-wise. Each step has a number of sub-steps (Fig 3.1) which have been briefly discussed in this chapter.



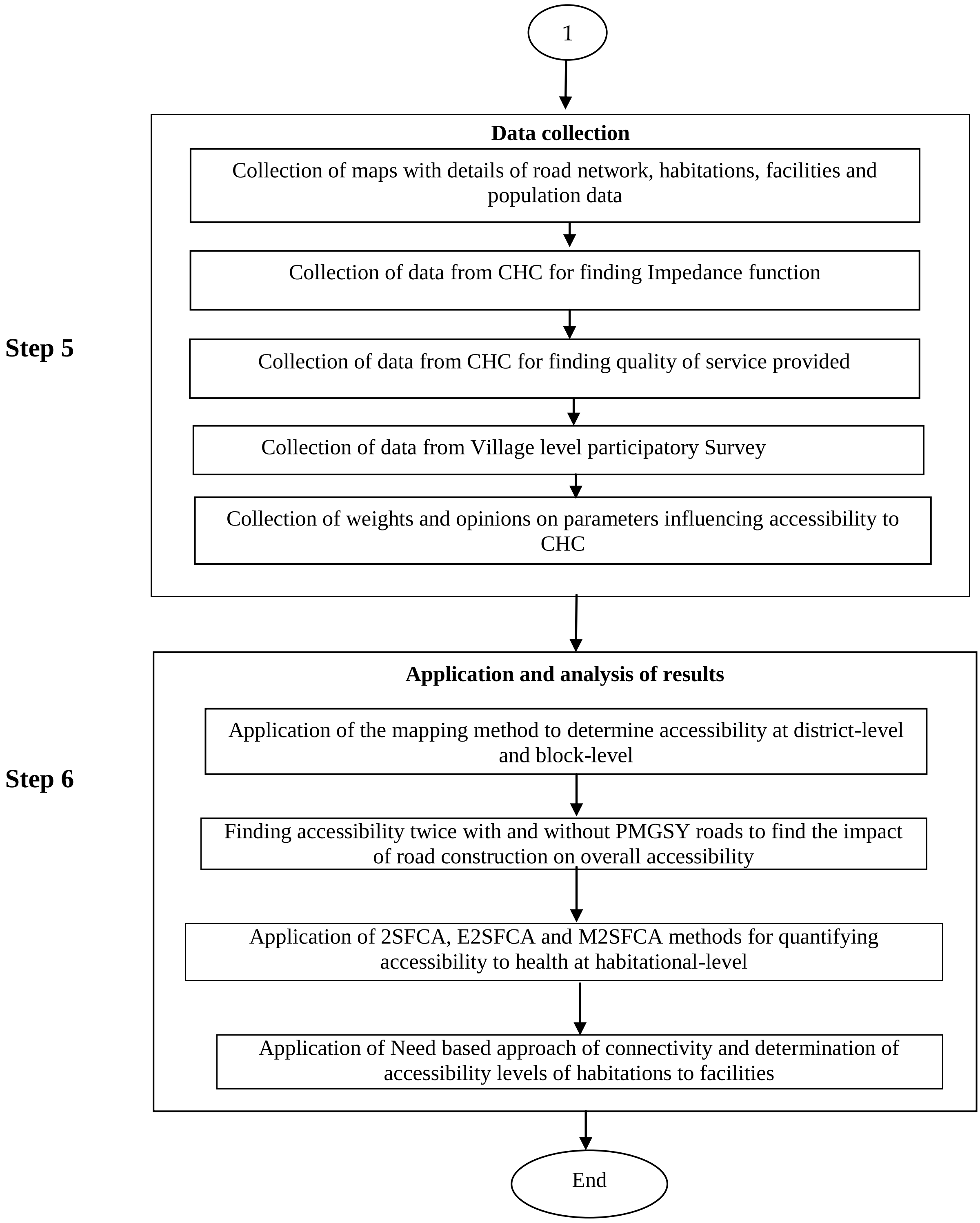


Fig 3.1: Various steps followed in the present study

Based on the review of literature presented in the preceding chapter, different methods have been designed for achieving objectives. The indicators developed by IDA has been used in the present study for quantifying accessibility at the regional level to all-weather roads and for finding out the impact of PMGSY roads on accessibility, which can be executed in GIS environment. After reviewing various accessibility measures developed in the past, it has been observed that most of the methods developed are urban specific, and there is no method that takes demand-supply, travel friction, quality of service (attractiveness) and mobility together into consideration for quantifying access. So in this study it has been decided to find the true accessibility values of the villagers by considering all the important factors that influence it. The 2SFCA and E2SFCA methods have been successfully used in different parts of the world to find access to health care at habitational level. In this study feasibility of application of this method has been checked for rural areas. To quantify accessibility at habitational level to health care, all the important parameters that influence access to health care in Indian rural context are considered and accordingly a method have been developed i.e., M2SFCA method.

From the literature, it has also been observed that not many researchers have developed a need-based approach for connecting habitations to improve overall accessibility. Thus, in this study a new method has been designed at the network level for connectivity which will help in enhancing access to all basic facilities.

Step 1: Development of methodology to quantify accessibility at the regional level

Rural Accessibility Index (RAI) suggested by International Development Authority (IDA) was used to find accessibility at regional level. RAI was later modified for Indian condition as per PMGSY accessibility definition. Moreover, for finding out the impact of PMGSY roads on accessibility, as per PMGSY definition, RAI values for each block and district were planned to be determined twice, one without PMGSY roads and the other one with the PMGSY roads. Thus the difference highlights the impact of PMGSY roads on accessibility.

Step 2: Development of methodology to quantify accessibility to health care at the habitational level

It was noted from the literature that two step floating catchment area methods are widely and successfully used by researchers to find access to health care. Therefore, initially in this study accessibility has been calculated using the existing methods, i.e., two step floating catchment area and enhanced two step floating catchment area for all the five districts. However, most of the application of floating catchment area methods developed were confined to urban areas and thus might not be suitable directly for rural conditions. Moreover the traditional methods have neglected few parameters which are quite important for Indian rural people. Therefore, keeping the above facts in view a methodology has been developed for quantifying accessibility to health care at habitational level by considering all the important factors influencing accessibility like mobility and quality of service.

Step 3: Development of a need-based network for rural connectivity

A need-based approach for rural connectivity which would ensure accessibility to the basic facilities has been developed and used to create links. Initially hypothetical links were planned to be created by connecting all unconnected habitations to nearby links. A facility search algorithm was developed, so to connect habitations to all the basic facilities within acceptable distances of travel. A prioritization technique was also developed to prioritize links for the type of construction using the scores on the purpose of travel and population to be served by the link.

Step 4: Selection of study areas

While dealing with a large area for accessibility measurement, the first step was to develop an identification method for the study areas and this was achieved by setting a criteria system. Considering the fact that the accessibility levels would vary with the spatial position of the villages, in the present study, five districts were considered based on the population density criteria.

Step 5: Data collection

With the methods finalized the data required to execute was decided. For the selected study areas, district maps were collected. The map shows the block boundaries, road network classification and habitation location. Additionally, population data about the habitations and availability of facilities data by respective districts were collected. Moreover, data regarding the visits of the patients for a month and the basic standard requirement for full operation of CHC were collected from the CHCs. A village level questionnaire was designed to collect villagers opinion on the parameters that influence accessibility to CHC.

Step 6: Application and analysis of results

Accessibility at the regional level was measured using GIS as per IDA and PMGSY definition. Mapping method has been used to find the accessibility levels. GIS environment has been utilized to execute the mapping method. District wise and then blocks wise accessibility values were calculated. Accordingly, ranking was done for improving accessibility.

Accessibility at habitational level was initially measured using 2SFCA and E2SFCA methods which include health care location, habitation locations and population data of the habitations to quantify access. In E2SFCA method an additional travel friction factor is used to find accessibility. The predicted accessibility values were compared with the observed accessibility values from the field by statistical methods. Then the developed modified two step floating catchment area (M2SFCA) method which encounters all the limitations of 2SFCA and E2SFCA methods was used to find accessibility. This method includes all the important factors influencing accessibility like mobility and quality of service. The results from this method were validated with observed accessibility values using statistical tests.

The need-based approach developed for road network planning was executed initially by creating a hypothetical links by connecting all unconnected habitations to nearby links or habitation. By using a facility search algorithm, all the habitations were connected to all the basic facilities which were within acceptable distances of travel. The connected links were given weightages based on the purpose of travel and population to be served by the link. Then the links were prioritized for deciding the type of surface to be provided.

Chapter 4

Data Collection

4.1. Background

The methodology proposed for the current study to measure accessibility at regional and village level required data collected from secondary sources and primary data through participatory surveys. Secondary data such as maps have been collected to carry out spatial analysis using GIS platform. To quantify accessibility at village level, a village level participatory survey has been conducted. Moreover the data regarding quality of service provided by the health centers, which depends on a number of parameters has also been collected. It is one of the most decisive parameters in the perspective of the villagers in visiting a specific health center.

It may be noted that this chapter only discusses the details of the data collection process, the analysis of the data has been presented in Chapters five, six and seven.

4.2. Selection of study areas

Considering the fact that the accessibility index would vary with the spatial position of the villages, in the study it was decided to consider state and districts having different spatial characteristics. Keeping the above fact in view the state of Rajasthan, India, which incorporates most of the wide spatial characteristics ranging from densely populated to sparsely populated areas, has been selected for detailed analysis. Five districts, with varying population densities have been selected for the detailed analysis.

The list of the districts selected for the study along with the population densities (as per 2011 census data) are shown in Table 4.1. It may be observed that population density varies widely with 78 population density per square kilometer to 438 in Alwar. The area in Bikaner is almost three times when compared to that of Alwar. The locations of selected districts in Rajasthan are shown in Fig 4.1. The maps of all districts with block boundaries and road network are presented in *Appendix 1*. Alwar and Tonk districts have plain landscape, whereas the other three districts are desert territories. Each district is divided into a number of blocks. A block is a district sub-division and it further consists of a number of habitations. In this study, district-level and block-level accessibility has been measured. Additionally, the habitational-level accessibility to Community health center (CHC) has also been measured. Details of a number of CHCs present in each district are presented in Table 4.2. The details of the blocks in all the districts with their population density are shown in Table 4.3.

Table 4.1. Details of districts selected for case study

S.No	District	Number of blocks	Population	Area(Sq km)	Population Density per sq km
1	Alwar	14	3671999	8385	438
2	Jhunjhunu	8	2139658	5923	361
3	Tonk	6	1421711	7184	198
4	Churu	6	2041172	13826	148
5	Bikaner	6	2367745	30292	78

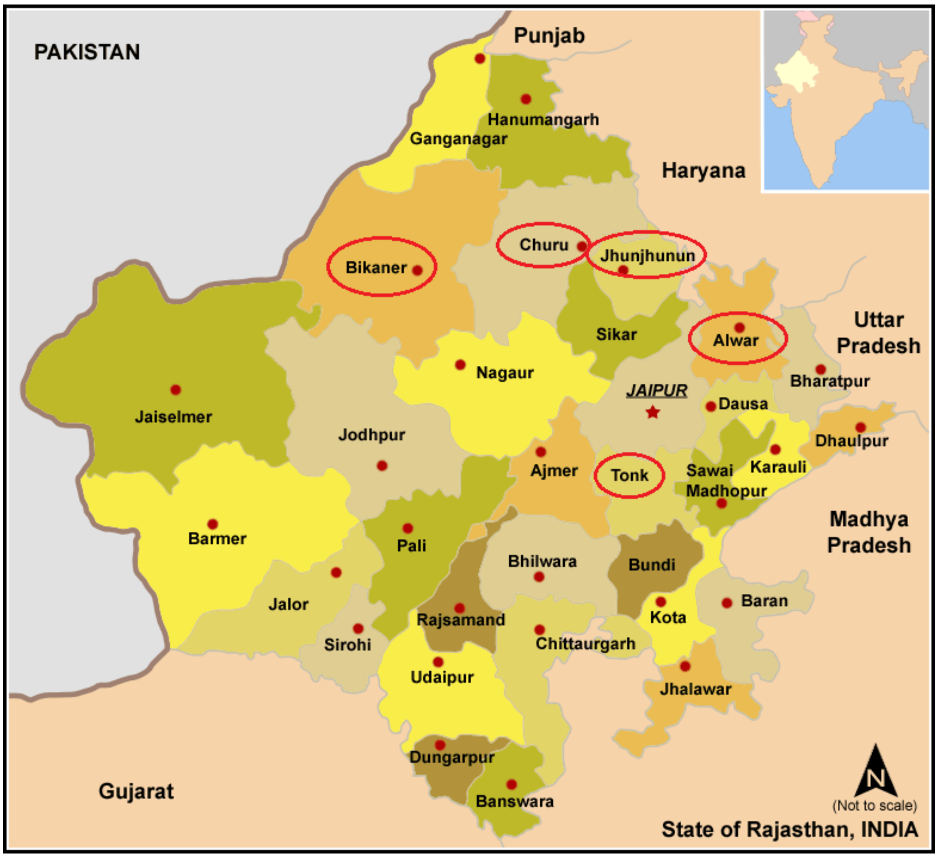


Fig. 4.1. Selected districts in the state of Rajasthan (Source: Maps of India)

Table 4.2. Number of CHCs in each district

S.No	District	Number of blocks	Number of CHCs	Number of habitations
1	Alwar	14	24	2217
2	Jhunjhunu	8	13	854
3	Tonk	6	7	1003
4	Churu	6	10	852
5	Bikaner	6	11	849

Table 4.3. Details of blocks

S.No	District	Block	Population density
1	Alwar	Bansur	463.56
2	Alwar	Behror	635.57
3	Alwar	Kathumbar	637.97
4	Alwar	KishanGarh Bas	451.89
5	Alwar	Kotkashim	569.85
6	Alwar	Lachmangarh	557.19
7	Alwar	Mundawar	515.09
8	Alwar	Nimrana	616.93
9	Alwar	Rajgarh	233.82
10	Alwar	Ramgarh	511.1
11	Alwar	Reni	445.43
12	Alwar	Thanaganzi	263.06
13	Alwar	Tijara	471.32
14	Alwar	Umren	249.41
15	Bikaner	Bikaner	110.93
16	Bikaner	Dungargarh	127.24
17	Bikaner	Kolayat	62.29
18	Bikaner	Lunkaransar	56.26
19	Bikaner	Nokha	87.07
20	Bikaner	Khajuwala	71.1
21	Churu	Churu	166.31
22	Churu	Rajgarh	209.36
23	Churu	Ratangarh	157.96
24	Churu	Sardarshar	101.34
25	Churu	Suiangarh	147.84
26	Churu	Taranagar	144.41
27	Jhunjhunu	Alsisar	293.69
28	Jhunjhunu	Buhana	499.99
29	Jhunjhunu	Chirawa	479.3
30	Jhunjhunu	Jhunjhunu	332.02
31	Jhunjhunu	Khetri	261.59
32	Jhunjhunu	Nawalgarh	466.09

S.No	District	Block	Population density
33	Jhunjhunu	Surajgarh	345.44
34	Jhunjhunu	Udaipurwati	307.27
35	Tonk	Deoli	190.94
36	Tonk	Malpura	179.67
37	Tonk	Niwai	241.72
38	Tonk	Todaraisingh	168.32
39	Tonk	Tonk	222.8
40	Tonk	Uniara	181.17

4.3. Collection of Data

The data collection process in the present research was planned meticulously and was implemented as per the following stages.

4.3.1. Collection of Maps

The maps of selected districts have been collected from the Public Works Department, Government of Rajasthan, Jaipur. The map of the district mentions the details of road networks and the location of the habitations. The functional classification of roads (National Highways, State Highways, Other District roads, Village roads and unpaved roads) are also highlighted on the map as shown in *Appendix 1*. The population of each habitation has been provided separately in an excel sheet.

4.3.2. Selection of blocks and habitations through sampling technique

As discussed in the methodology, data collection is required to find out travel friction factor, quality of service of health care and mobility. Keeping the time and money constraint in mind it was decided that it is not feasible to collect data for all the health centers and habitations in the five districts. Therefore, sampling of blocks and then habitations has been done to collect data.

To finalize the blocks for conducting the survey the following criteria were kept in mind:

- The block should closely represent the characteristics of the whole district in terms of population density.
- The block should also roughly represent the pattern of location of health centers.

And also for the ease of collection of data, in consultation with local NGOs the blocks have been selected for the study. Details of block selected for the study in all the five districts based on above criteria are shown in the Table 4.4.

The habitations for the village level participatory questionnaire survey were selected based on following criteria:

- The selected habitations have different travel distances from the community health center (CHC).
- The habitations essentially have a sub-center within it and a primary health center (PHC) within 5 km radius.
- Essentially a representative sample group of the population visits the nearest CHC.
- The travel distance of habitation from the CHC should be a maximum of 15 km.

The main criterion for choosing sample habitations was population. The population of Alwar district is approximately about 1.7 times more than the other four districts (table 4.1). Although the number of habitations in other districts are more when compared to Alwar, the population in many habitations is very less i.e., less than 50. Therefore in Alwar district comparatively more number of habitations were surveyed. Accordingly different margins of error have been chosen all below 15% at 95% confidence level. The Sample Size Calculator presented by Creative Research Systems (survey software) has been used to calculate sample size. The sample number of the habitations collected in each district is shown in Table 4.4.

Table 4.4. Details of blocks and the number of habitations selected for village level survey

S.No	District	Block	No of habitations	Sample habitations	Confidence Interval (%)
1	Alwar	Nimrana	93	76	5
2	Bikaner	Lunkaransar	112	50	10
3	Churu	Ratangarh	100	50	10
4	Jhunjhunu	Buhana	125	50	11
5	Tonk	Niwai	191	50	12

4.3.3. Data collection for finding accessibility to CHC at habitational-level

Initially from the literature review and the methodology finalized, a speculative questionnaire was prepared keeping the objectives in view. As a prerequisite for conducting the study, a chosen set of enumerators from a Non-Government Organizations (NGOs) was trained in the collection of data at all the levels. They were also trained in the field to ensure the accuracy and uniformity in the data collection process. A pilot study was conducted by posing the questionnaire to the villagers and then it was modified according to the inputs received from the villagers and the enumerators. Mainly three types of data were collected for executing the methodology proposed in chapter 3 and they are discussed below in detail.

4.3.3.1. Data collection for calculating Travel Friction factor

For calculating weights for the travel distance, i.e. to adjust travel impedance consistent with the travel behavior of the villagers information was gathered from the register of the CHCs. The register keeps the records of patients originating from different villages and visiting a particular CHC. The information was gathered in the month of November as it was mentioned by the physicians in CHCs that usually they observe a high demand during this time of year. The format for the data collected from a CHC has been provided in *Appendix 2.*

4.3.3.2. Data collection to quantify the quality of CHC

The second set of data collection was intended to evaluate the sufficiency and availability of manpower and infrastructure of the chosen CHCs. The standard format used by Indian Public Health Services (IPHS) to evaluate the standard of CHCs was used as the base document for data collection. The topics of the CHC format as given by IPHS were clinical manpower, support manpower, physical infrastructure, service facilities and lab facilities. The formats were sub-divided according to major areas. Keeping in view the objectives of the study the standard format was modified so as to include the service related questions only. The format used to evaluate the standard of services offered by CHCs is shown in *Appendix 3.* Data was collected from all the functioning CHCs of the selected blocks in a district with the help of block health officials and NGOs. The respondent of the study was the person in-charge of the CHC.

4.3.3.3. Data collection to quantify mobility and opinion of villagers on health services

To determine the opinion of the villagers on the health services provided by the CHCs and furthermore to quantify their mobility, an extensive structured questionnaire was developed for conducting field survey. The questionnaire mainly included questions related to general information about the villagers, the details of travel (travel distance, travel time, travel costs, the usual mode of travel) to the health center and their experience at the health center (waiting time, availability of medicine, physician and conduct of the doctor). The villagers were also interviewed about their overall satisfaction with the present level of access to CHC and overall satisfaction with the health services provided by the CHC. Also the respondents were requested to assign weights on the parameters in the light of their satisfaction in defining accessibility to health care facilities, on a scale of 1 to 5, 5 representing highly satisfied, 4-satisfied, 3-undecided, 2-dissatisfied and 1 highly dissatisfied. All the subjective information has been gathered on the Linguistic scale and all other quantitative parameters in absolute values. The questionnaire developed for the collection of data is given in *Appendix 4*. The data were collected at village level using participatory approach for both males and females separately. The Fig 4.2 shows the participatory approach of a group survey for females using participatory approach.

Fig. 4.2. Participatory approach of a group survey for females

Chapter 5

Quantification of Accessibility at the Regional Level and Assessment of Impact of All-Weather Roads on Accessibility

5.1 Background

Enhancing physical access and mobility is the prime factor for reducing poverty in rural areas. The transport sector of the World Bank has determined headline transport indicators to implement wider development process. Headline transport indicators include a number of key diagnostic measures which have particular significance for the sector. This study utilizes Rural Access Index (RAI), one of the several transport headline Indicators suggested by the World Bank Transport Sector Board in 2003. RAI has been adopted for the Results Measurement System (RMS) of the 14th round of the International Development Association (IDA-14) which was launched in July 2005. RAI is used as a tool for policy makers for allocating resources. RAIs internationally established definition for a region is the proportion of the number of rural people who live within two kilometers (typically equivalent to a walk of 20-25 minutes) of an all-weather road to the total rural population. Under the PMGSY guidelines, a habitation is considered to have connectivity, if there is an existing all weather road within 500 meters of the habitation (in case of hilly and desert areas the path distance is 1.5 km). In the areas considered for the study, Jhunjhunu, Churu and Bikaner districts are desert areas. In this study, overall accessibility at block-level and district-level is measured as per IDA definition and PMGSY definition.

Rural Accessibility Indicator as per IDA criterion RAI (IDA) is expressed as Eq 5.1.

$$\text{RAI (IDA)} = \frac{\text{Population living within 2.0km band on both sides of all-weather roads}}{\text{Total population of the block}}\ 100 \qquad (5.1)$$

Rural Accessibility Indicator as per PMGSY criterion RAI (PMGSY) in plain terrain is expressed as Eq 5.2.

$$\text{RAI (PMGSY)}_{\text{Plain}} = \frac{\text{Population living within 0.5 km band on both sides of all-weather roads}}{\text{Total population of the block}} \times 100 \qquad (5.2)$$

Accessibility Indicator as per PMGSY criterion AI (PMGSY) in hilly terrain and desert areas) is expressed as Eq 5.3.

$$\text{RAI (PMGSY)}_{\text{Hills}} = \frac{\text{Population living within 1.5 km band on both sides of all-weather roads}}{\text{Total population of the block}} \times 100 \quad (5.3)$$

According to IDA, there are two main approaches to the measurement of this indicator: (1) household surveys that include information about access to transport, and (2) mapping data to determine how many people live within the specified catchments of the road network. In this analysis the second method is used to measure RAI as per IDA and PMGSY definition using GIS platform. The populations within the bands such as 2 km and 0.5 km are found using the buffer tool in ArcGIS 10.2.

5.2 Accessibility by Mapping Method

ArcGIS software 10.2 has been used to determine the accessibility levels using mapping method. The map was geo-referenced, i.e., it was oriented in the geographic North-South directions. In all the five districts namely Alwar, Jhunjhunu, Tonk, Churu and Bikaner, the all-weather road network with PMGSY links and without PMGSY links were separately digitized. Similarly, all the habitations of the block were digitized. For example, the road network and the habitations of the Alwar district is shown in the Fig 5.1, digitized.

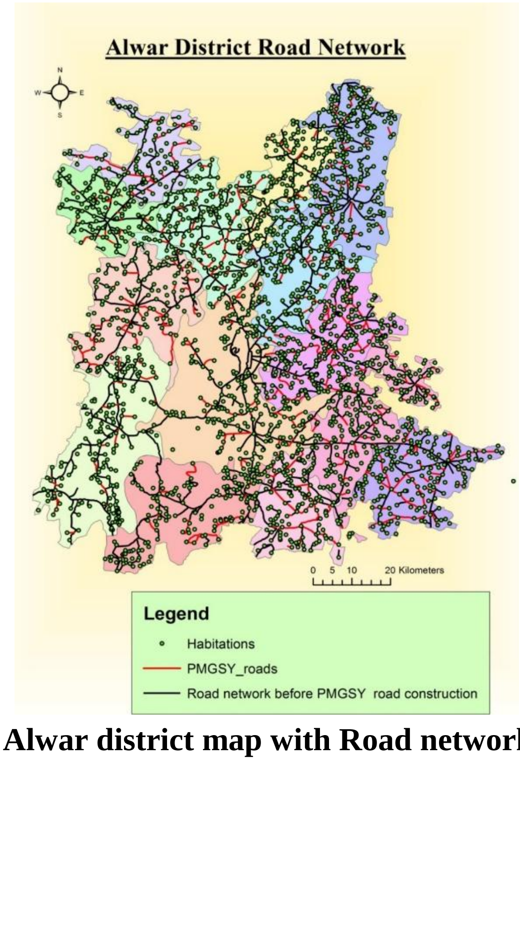


Fig 5.1: Alwar district map with Road network and habitations

Initially for the all-weather road network without PMGSY roads, a buffer at a distance of 500 meters on either side of the road width was drawn using the buffer tool in GIS platform. The map of Alwar district has been shown in Fig. 5.2 as an example. The villages which are not falling within the band width are shown in red color. The proportion of population falling within the bandwidth to the total population of the block has been calculated to determine RAI(PMGSY) for each district.

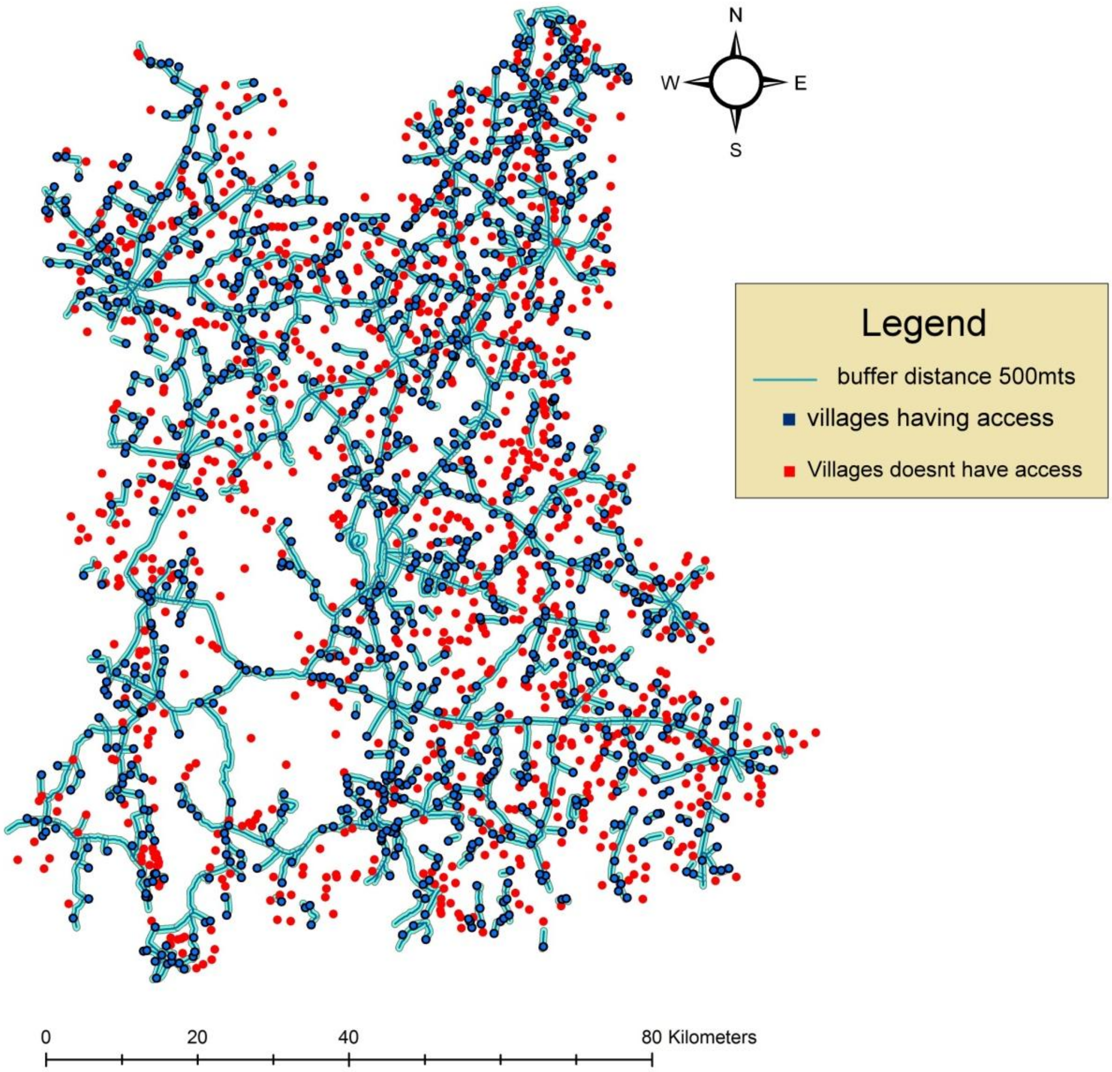


Fig 5.2. Map of Alwar District, Rajasthan with 500 mts bands without PMGSY roads and the location of villages

Similarly for the road network with PMGSY roads, the proportions of the number of people within ±500 meter bandwidth were calculated. The map of Alwar district has been shown in Fig 5.3 as an example. From contrasting Fig 5.2 and 5.3 it might be noticed that the number of villages which do not have access are fewer after the construction of PMGSY roads. The difference between the RAI values with PMGSY and without PMGSY roads gives the impact of construction of PMGSY roads on the overall accessibility of the districts. In parallel the RAI values are calculated using IDA definition, i.e., the proportion of the population of habitations falling within 2 km of bandwidth to the total population. The RAI values calculated using the IDA definition provides a broad understanding about accessibility in international terms.

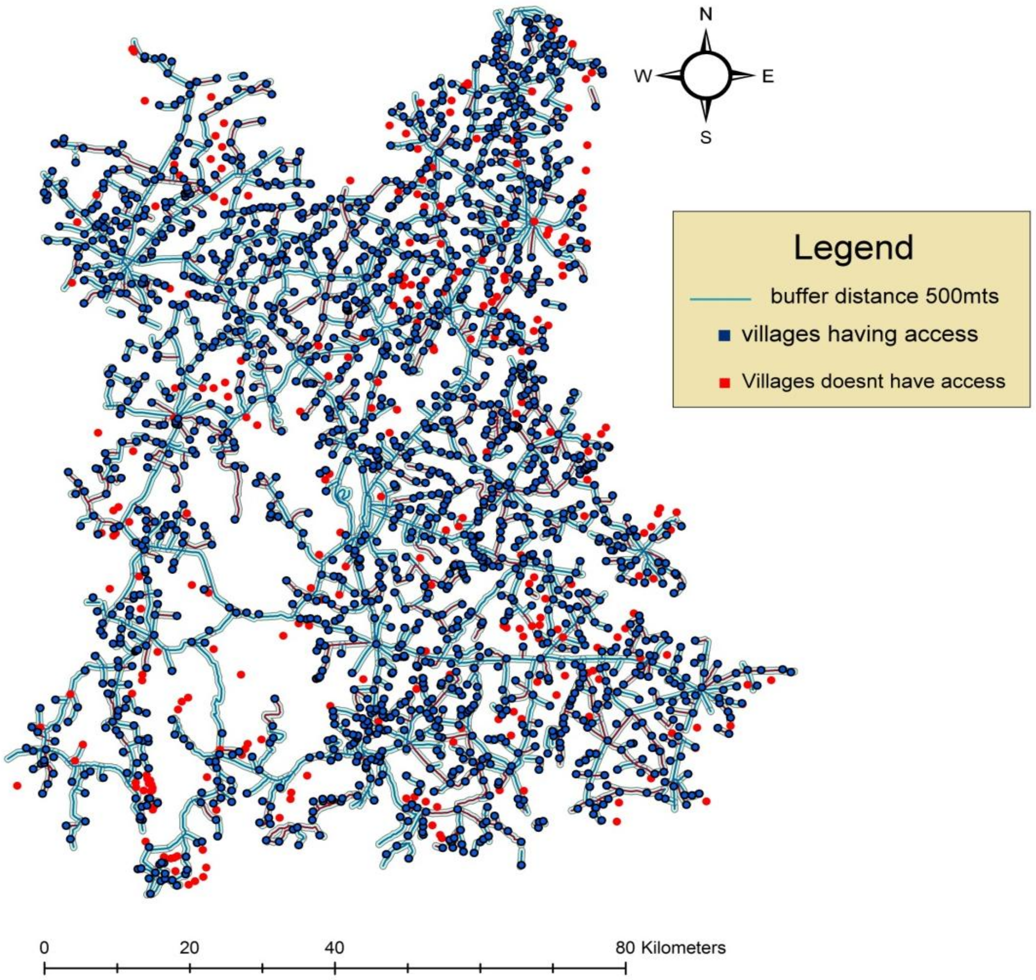


Fig 5.3. Map of Alwar District, Rajasthan with 500 mts bands with PMGSY roads and the location of villages

5.2.1. District-wise analysis

While contrasting among the five districts, the effect of the development of PMGSY streets is the least in Bikaner region. The reason could be that the district is sparsely populated and by the construction of unit road length, accessibility does not improve much as not many villages come within the range of defined accessibility. The impact of

PMGSY roads in different districts is shown in Table 5.1 and in the form of bar charts in Fig 5.4. From the table it can be observed that although the total road length of PMGSY constructed is high in Alwar (676.5 km) and Bikaner (584.2 km) districts, but the impact on accessibility is more in Alwar district (19.14%).

Table 5.1. RAI (in percent) in District-wise

RAI (in percent)							
District	PMGSY road length constructed (km)	Buffer Distance					
		0.5KM (PMGSY)			2KM (IDA)		
		With PMGSY	*Without PMGSY*	*Difference*	*With PMGSY*	*Without PMGSY*	*Difference*
Alwar	676.5	63.74	44.6	19.15	67.84	62.71	5.13
Jhunjhunu	499.1	64.43	48.22	16.21	64.86	50.78	14.08
Tonk	459.3	57.59	40.31	17.28	58.49	46.43	12.06
Churu	543.4	55.31	37.42	17.9	57.59	41.66	15.93
Bikaner	584.2	55.15	41.84	13.31	57.35	47.01	10.35

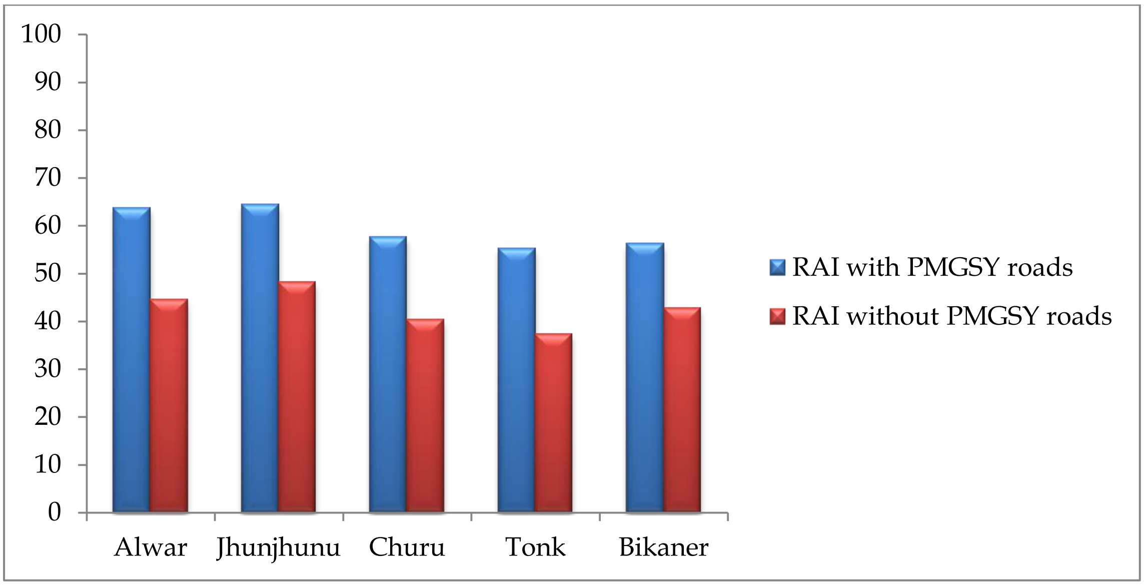


Fig 5.4. Bar chart showing RAI values calculated with and without PMGSY roads.

5.2.2. Block-wise analysis

Using the same method as used for determining RAI values for the districts, the block-level values were also calculated for all the districts. It may be noted that depending on the population and the size of the districts, there are varying number of blocks. There are 14 blocks in Alwar, 8 in Jhunjhunu, 6 each in Tonk, Churu and Bikaner. The results for block-wise analysis are shown in Table 5.2. The impact of construction of PMGSY roads on overall accessibility is more when calculated using PMGSY definition as a part of comparison to the IDA definition as most of the all-weather roads constructed by PMGSY are less than 2 km. The impact of PMGSY roads on overall accessibility ranges from 32 to 3 percent in different blocks.

Table 5.2. RAI (in percent) in Block-wise

RAI (in percent)								
S.No	District Name	Block Name	Buffer Distance					
			(PMGSY)			(IDA)		
			With PMGSY (Present RAI)	*Without PMGSY*	*Difference*	*With PMGSY*	*Without PMGSY*	*Difference*
1	Alwar	Bansur	63.31	33.95	29.35	67.27	60.66	6.61
2	Alwar	Behror	65.67	52.71	12.97	68.21	67.21	1
3	Alwar	Kathumbar	65.34	39.01	26.34	67.96	59.18	8.78
4	Alwar	Kishan Garh Bas	60.84	44.53	16.31	68.21	64.51	3.7
5	Alwar	Kotkashim	64.06	53.01	11.05	68.21	67.38	0.83
6	Alwar	Lachmangarh	60.71	48.27	12.44	67.65	66.13	1.52
7	Alwar	Mundawar	65.87	42.36	23.51	68.01	62.46	5.55
8	Alwar	Nimrana	63.08	44.41	18.67	67.59	59.31	8.28
9	Alwar	Rajgarh	61.81	47.45	14.36	67.54	62.62	4.92
10	Alwar	Ramgarh	63.68	31.61	32.07	67.95	55.61	12.33
11	Alwar	Reni	64.67	44.06	20.61	68.21	65.98	2.23
12	Alwar	Thanaganzi	63.09	52.83	10.26	66.84	63.66	3.18
13	Alwar	Tijara	64.37	50.94	13.43	68.1	66.55	1.55
14	Alwar	Umren	65.21	48.17	17.04	68.04	60.65	7.39
15	Jhunjhunu	Alsisar	64.23	51.44	12.8	65.24	52.9	12.31
16	Jhunjhunu	Buhana	66.53	56.97	9.57	66.53	57.54	9
17	Jhunjhunu	Chirawa	63.4	49.35	14.05	64.11	54.42	9.69
18	Jhunjhunu	Jhunjhunu	64.15	49.75	14.4	64.15	54.6	9.55
19	Jhunjhunu	Khetri	62.85	44.62	18.23	62.85	48.91	13.94
20	Jhunjhunu	Nawalgarh	62.9	43.02	19.89	64.54	45.82	18.73
21	Jhunjhunu	Surajgarh	64.75	46.43	18.33	64.75	47.38	17.38
22	Jhunjhunu	Udaipurwati	66.06	43.32	22.75	66.06	44.78	21.29
23	Tonk	Deoli	58.49	55.52	2.96	58.67	42.73	15.94
24	Tonk	Malpura	53.47	25.57	27.9	59.09	50.68	8.42
25	Tonk	Niwai	58.99	48.52	10.48	58.18	51.07	7.1
26	Tonk	Todaraisingh	58.87	37.53	21.34	58.77	37.52	21.25
27	Tonk	Tonk	58.61	44.66	13.96	58.22	46.14	12.08
28	Tonk	Uniara	58.97	40.05	18.92	57.95	47.64	10.32
29	Churu	Churu	56.9	53.37	3.54	58.83	56.51	2.32
30	Churu	Rajgarh	49.57	21.31	28.27	52.97	27.62	25.35
31	Churu	Ratangarh	58.09	47.67	10.42	58.99	49.16	9.83
32	Churu	Sardarshar	57.22	35.2	22.02	58.92	38.36	20.56
33	Churu	Suiangarh	55.08	40.52	14.57	58.89	46.26	12.63
34	Churu	Taranagar	58.51	37.82	20.7	59.03	41.63	17.4
35	Bikaner	Bikaner	65.3	55.94	9.36	68.6	57.26	11.35
36	Bikaner	Dungargarh	63.79	39.89	23.9	70.94	46.05	24.89
37	Bikaner	Kolayat	28.38	19.3	9.08	29.88	20.81	9.07
38	Bikaner	Lunkaransar	81.43	62.59	18.84	81.55	63.24	18.32
39	Bikaner	Nokha	70.86	48.8	22.05	74.47	64.89	9.59
40	Bikaner	Khajuwala	38.39	29.29	9.1	42.29	40.13	2.16
		Average present RAI	60.5					

The district-wise and then block-wise ranking based on the present RAI values are shown in Table 5.3. RAI values calculated using the total road network, including PMGSY links (as per PMGSY criterion) are the present RAI values of the districts and blocks shown in table 5.3. From the district-wise ranking it is observed that Bikaner district has the lowest present accessibility values. A policy decision maker can plan to improve the present accessibility level of this district by attaining block-wise. Based on the availability of funds for development, the decision makers can take different policy decisions. For example, the priority of enhancement can be based on the ranking of blocks in each district as shown in table 5.3 or the priority can be given by considering all the 40 blocks together as shown in table 5.4. It may be noted that in about 75% of the blocks the present average accessibility level is over 60%. However, in the few blocks of Bikaner and Churu districts which have low population density has RAI value less than 50%. The blocks already having relatively higher accessibility values did not have PMGSY advantage essentially. The policy makers can also use the calculated average RAI value of 60% as a benchmark and try to achieve the average accessibility values for the blocks falling behind. The benchmark value can be increased accordingly over a period of time based on the funds available.

Table 5.3. District-wise ranking based on RAI

District-wise ranking	Present District-wise RAI	District	Block	Present Block-wise RAI	Block-wise ranking
1	53.38355	Bikaner	Kolayat	28.38	1
			Khajuwala	38.39	2
			Dungargarh	63.79	3
			Bikaner	65.3	4
			Nokha	70.86	5
			Lunkaransar	81.43	6
2	56.38355	Churu	Taranagar	58.51	6
			Ratangarh	58.093	5
			Sujangarh	55.08	2
			Churu	56.9	3
			Sardarshar	57.22	4
			Rajgarh	49.57	1
3	57.581146	Tonk	Malpura	53.47	1
			Deoli	58.49	2
			Tonk	58.61	3
			Todaraisingh	58.87	4
			Uniara	58.97	5
			Niwai	58.99	6

District-wise ranking	Present District-wise RAI	District	Block	Present Block-wise RAI	Block-wise ranking
4	63.732844	Alwar	Lachmangarh	60.71	1
			Lachmangarh	60.71	1
			Kishan Garh Bas	60.84	2
			Rajgarh	61.81	3
			Nimrana	63.08	4
			Thanaganzi	63.09	5
			Bansur	63.31	6
			Ramgarh	63.68	7
			Kotkashim	64.06	8
			Tijara	64.37	9
			Reni	64.67	10
			Umren	65.21	11
			Kathumbar	65.34	12
			Behror	65.67	13
			Mundawar	65.87	14
5	64.425306	Jhunjhunu	Khetri	62.84	1
			Nawalgarh	62.9	2
			Chirawa	63.39	3
			Jhunjhunu	64.14	4
			Alsisar	64.23	5
			Surajgarh	64.75	6
			Udaipurwati	66.06	7
			Buhana	66.53	8

Table 5.4. Block-wise ranking based on RAI

S.No	District Name	Block Name	RAI (in percent) as per PMGSY criterion	Rank
1	Bikaner	Kolayat	28.38	1
2	Bikaner	Khajuwala	38.39	2
3	Churu	Taranagar	46.58	3
4	Churu	Ratangarh	52.03	4
5	Churu	Suiangarh	53.1	5
6	Tonk	Malpura	53.47	6
7	Churu	Churu	54.14	7
8	Churu	Sardarshar	56.64	8
9	Churu	Rajgarh	56.69	9
10	Tonk	Deoli	58.49	10
11	Tonk	Tonk	58.61	11
12	Tonk	Todaraisingh	58.87	12
13	Tonk	Uniara	58.97	13
14	Tonk	Niwai	58.99	14
15	Alwar	Lachmangarh	60.71	15
16	Alwar	Kishan Garh Bas	60.84	16

S.No	District Name	Block Name	RAI (in percent) as per PMGSY criterion	Rank
17	Alwar	Rajgarh	61.81	17
18	Jhunjhunu	Khetri	62.84	18
19	Jhunjhunu	Nawalgarh	62.9	19
20	Alwar	Nimrana	63.08	20
21	Alwar	Thanaganzi	63.09	21
22	Alwar	Bansur	63.31	22
23	Jhunjhunu	Chirawa	63.39	23
24	Alwar	Ramgarh	63.68	24
25	Bikaner	Dungargarh	63.79	25
26	Alwar	Kotkashim	64.06	26
27	Jhunjhunu	Jhunjhunu	64.14	27
28	Jhunjhunu	Alsisar	64.23	28
29	Alwar	Tijara	64.37	29
30	Alwar	Reni	64.67	30
31	Jhunjhunu	Surajgarh	64.75	31
32	Alwar	Umren	65.21	32
33	Bikaner	Bikaner	65.3	33
34	Alwar	Kathumbar	65.34	34
35	Alwar	Behror	65.67	35
36	Alwar	Mundawar	65.87	36
37	Jhunjhunu	Udaipurwati	66.06	37
38	Jhunjhunu	Buhana	66.53	38
39	Bikaner	Nokha	68.86	39
40	Bikaner	Lunkaransar	69.43	40

5.2.3. Relation between population density and road length

The maximum impact of PMGSY in terms of RAI has been observed in Alwar district. It is also noted that Alwar has maximum population density. Higher the population density, i.e., more closer the habitations the lesser roads required to connect the habitations. A relation is plotted between population density and total road length required to connect the habitations (Fig 5.5). It has also been observed that when the population density is low, the total road network length of that block is high. For example, in the figure it can be observed that for blocks of Alwar district whose population density is high, the total road length constructed to achieve present RAI is less as compared to Bikaner district with low population density.

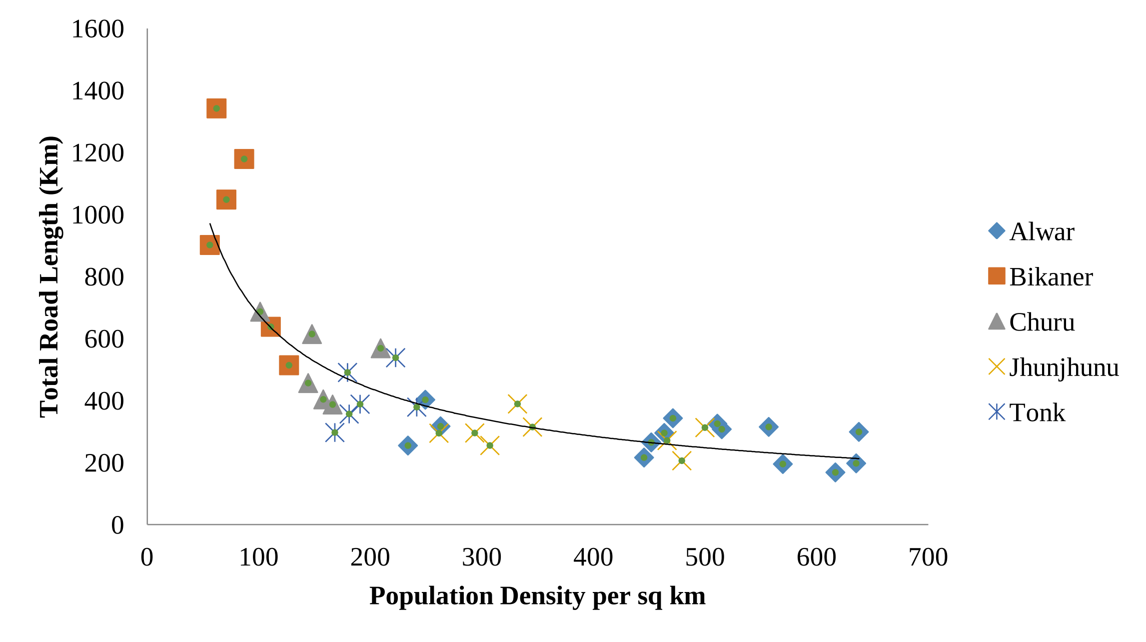


Fig 5.5. Relationship between population density and total road length

5.3 Summary

In this chapter, quantification of accessibility to all weather roads at the regional level has been discussed in detail. The rural accessibility Index was found as per IDA definition and PMGSY definition. The relation between accessibility and population density has also been discussed. The calculation of the impact of PMGSY road construction on rural accessibility has been presented in this detail. Finally, the prioritization or ranking of blocks and districts based on the accessibility index values is also presented.

Chapter 6

Quantification of Accessibility to Health Care at Habitational Level

6.1. Background

Connecting a habitation by all-weather road or access to all-weather road does not ensure access of the village to basic amenities. From the regional-level analysis (discussed in detail in chapter 5), it has been felt that there is a need for micro level analysis at habitation-level.

The two step floating catchment area (2SFCA) method has been recognized by the researchers as a key measure of spatial accessibility, especially in its application to essential medical services access. The 2SFCA technique is an ideal tool to quantify access to health care as it has the vast majority of the benefits of a gravity model and moreover on the other hand is easy to interpret because it basically uses an uncommon type of physician-to-population proportion. Fundamentally, the 2SFCA technique measures spatial accessibility as a proportion of health care physicians to population. It is easy to execute using GIS.

Numerous latest modifications to the first 2SFCA technique have been suggested, which for the most part either represent separation inside of a catchment (distance decay) or enable the utilization of variable catchment sizes. However, some of the important parameters such as quality of the health center and perception of the people on the service provided at the health center were not considered in most of the studies conducted using application of two step floating catchment area (2SFCA) method. Furthermore, most of the studies did not find the impedance function to calculate distance decay, which could be preferably found from the calibration stage of trip generation models taking into account observed travel behaviour. It might be due to the lack of information on the revealed spatial behaviour of population at different locations. And application of 2SFCA and enhanced two step floating catchment area (E2SFCA) methods were mostly bounded to urban areas. Therefore, in this study the scope of application of existing methods, i.e., 2SFCA and E2SFCA have been applied for the determination of accessibility to health in rural areas. Moreover, keeping in view the limitations and gaps in the previous studies, in this study a methodology named modified two-step floating catchment area Method (M2SFCA) has been proposed to quantify access to Community health center (CHC).

In this study accessibility to CHC in rural areas has been calculated using the following three methods

1. Two-step Floating Catchment Area Method (2SFCA)
   In 2SFCA method accessibility is calculated in two steps as it gets area twice taking into account population demand and health care supply
2. Enhanced two-step floating catchment area Method (E2SFCA)
   In E2SFCA method accessibility is likewise ascertained in two steps considering population demand and health care supply and furthermore differentiating the accessibility within a catchment area by utilizing distance decay functions.
3. Modified two-step floating catchment area Method (M2SFCA)
   In M2SFCA method, the E2SFCA method is further modified by including quality of service provided by the health cares and the mobility of the villagers.

6.2. Two-Step Floating Catchment Area Method (2SFCA)

Two-step floating catchment area method (2SFCA) is an enhancement of the floating catchment area method which considers only supply and ignores the demand side of the equation. 2SFCA method catches area twice based on population demand and health care supply. It is a form of physician to population ratio (Luo and Yi, 2009).

In traditional 2SFCA methods, in the first step number of physicians to population ratio at a health center, CHC in the study, within the catchment area is calculated. But in this study, accessibility is calculated to a particular type of health center, which is supposed to deliver the same service with the same number of physicians. Therefore, in the first step the influence or service area of a health facility is to be determined in terms of a specified distance using the existing road network. The service area or influence area is determined based on the threshold distance that a health center can serve. This also helps to determine the proportion of the population served by each individual health center. However, there is a possibility that a village will come under the service area of more than one health center. Thus the consequence of overlapping of service areas is accounted for in the second step. The accessibility level of each village is then determined in the second step by summing up the initial ratios falling within the acceptable distance of travel to the health center, CHC, by the villagers. It has been observed that in rural areas in India, a large portion of the roads connecting the habitations are unpaved making the travel difficult. Thus to differentiate the ease in travelling a paved and unpaved roads, a weight has been added while travelling on an unpaved road.

Step 1: Health Centre (HC) to population (P) ratio

For each health center location j, search for all the population or habitation locations (k) that are within the threshold travel distance (d_0) from a given location j and the computation of heath care to population ratio, R_j, within the catchment area is derived using Eq. 6.1.

$$R_j = \frac{HC_j}{\sum_i P_i} \tag{6.1}$$

Where,

P_i Population in habitation i

HC_j Number of health centers at j

R_j health care to population ratio at location j whose centroid falls within the catchment

Step 2: Accessibility Index of the population is calculated using Eq. 6.2

$$A_i = \sum_j (R_j * F_j)$$

$$F_j = \frac{d_m - d_{ij}}{d_m} \tag{6.2}$$

Where,

d_{ij} the distance travelled on the Unpaved road between habitation location i and Health center j.

d_m maximum threshold travel distance

A_i accessibility of the population at a given location i to health care

F_j Impedance weightage for traveling on Unpaved road to reach health center j

A greater value of A_i indicates that a particular population has better access to health care and is in a more advantageous position in terms of accessing CHC. This also helps in identifying the individual and cluster of villages having poor access to health care facilities.

Defining distance measurement

The crucial point in measuring accessibility is defining distance to access health facilities. There are different types of distances such as Euclidean distance, Manhattan distance, time-distance and network distance. The most realistic and precise measure is time-distance i.e., travel time. However, it has been observed that acquiring travel time data for Indian rural areas is not usually easy. It becomes further difficult as people might be using different modes of travel. Therefore, it has been decided that network distance will be a good approximation of time-distance. This has been used in the all the three methods, and the travel distance has been determined using the road network distance through the shortest route.

Selection of catchment area for step 1 in 2SFCA method

As mentioned in the methodology in the first step of 2SFCA method the proportion of the population served by each CHC within the catchment area is calculated. The service area or influence area is determined based on the threshold distance that a health center can serve. The quality of service provided by a health center depends on the infrastructure available, the quality of physicians and their availability. Also, while setting up a health center, the Government of India has developed Public Health Standards (IPHS) in this regard. The average radial distance covered by a CHC is 14.33 km as per a study conducted by IPHS in India in 2012 (MOHSW, 2012). In alternate words CHC is located to serve population within the radial distance of 15 km. In general, government sets up CHC at a location based on population norms. A CHC is provided to serve a population of 1,20,000 to 80,000. However, from the present study it has been noted that to reach this population in densely populated areas, CHC covers population within less than 15 km. And in the low population density areas, sometimes people have to travel for more than 40 km for the achievement of 80,000 population coverage by CHC. People in these areas are forced to travel for more than average distance of 15 km to get the service. Thus, for this study it was decided to consider 15 km road distance to define the catchment area for a CHC.

Selection of catchment area for step 2 in 2SFCA method

It has been noted from the literature that the size of the catchment does not have to be the same for step 1 and step 2 (Mao et al., 2011). Health centers may serve a large area, requiring large catchment for step 1 but the population may not be willing to travel larger distances but might be forced because of their captivity. Hence it was decided to find perceived acceptable distance of villagers to access health care. The acceptable distance is defined as the distance within which the villagers feel easy and comfortable enough to travel. It varies with factors such as population density, geographical terrain, socioeconomic factors of the individuals, road condition and availability of public transport in the locality. A survey was conducted in the selected villages to determine the acceptable road distance to CHC and it was found to be 15 km, which was quite close to the government norms.

Execution of 2SFCA method using GIS

In the first step of analysis, ArcGIS 10.0 has been used for geo-referencing and to digitize the location of villages, CHC locations and the existing road network. For example, digitized map of Alwar district is shown in Fig 6.1. GIS network analysis tool (closest facility) was used to execute the 2SFCA method. The inputs of the tool were the road network, demand or incident locations (habitations) and the supply or facility locations (i.e., CHC). The impedance distance or the search distance is 15 km network road length from CHC. As per PMGSY definition a habitation is accessible if it falls within 500m from the road network for the plain terrains, whereas 1500m for hilly and difficult terrains (desert areas). In this study the same has been used as input while executing closet facility tool. In other words the habitation which falls within 500m (for plain terrain) distance from an all-weather road is considered to have road connectivity. In the regions of study, Alwar and Tonk districts have plain terrain, while the other three chosen regions are desert areas. The outcome of the GIS analysis is the habitations falling within the threshold distance of the health centers and the distance from them.

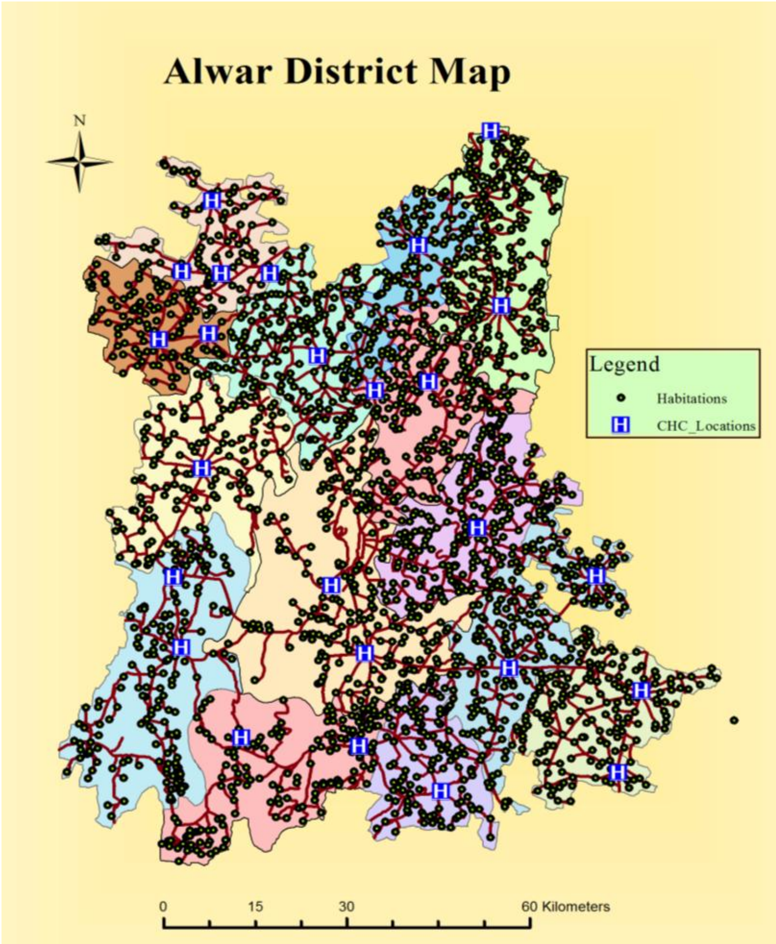


Fig 6.1: Map of Alwar District with Health Centers and Habitations

In this analysis for the location of a facility, depending on the influence distance, it calculates R_j by dividing one (for one health centre) by the total population falling within the influence distance. This is obtained by adding the population of all the villages that are within 15km road distance from a health centre. Next the catchment areas of all the health centers in the study area were obtained using service area tool in network analysis. Different shapes of catchment areas for different health centers were observed as the influence distance following actual network distances. The extreme points of the influence distance on different roads in the network were then joined by lines to describe service areas. The villages not included in the service areas were considered as inaccessible to health care facility. The service areas (catchment areas) in Alwar district are shown in Fig 6.2 and the areas not served could be clearly identified from the map. An example has been shown in figure 6.3 where within the influence area of health centre X, there are connected habitations with a total population of 44060. The R_j value of the health center X is 0.000022.

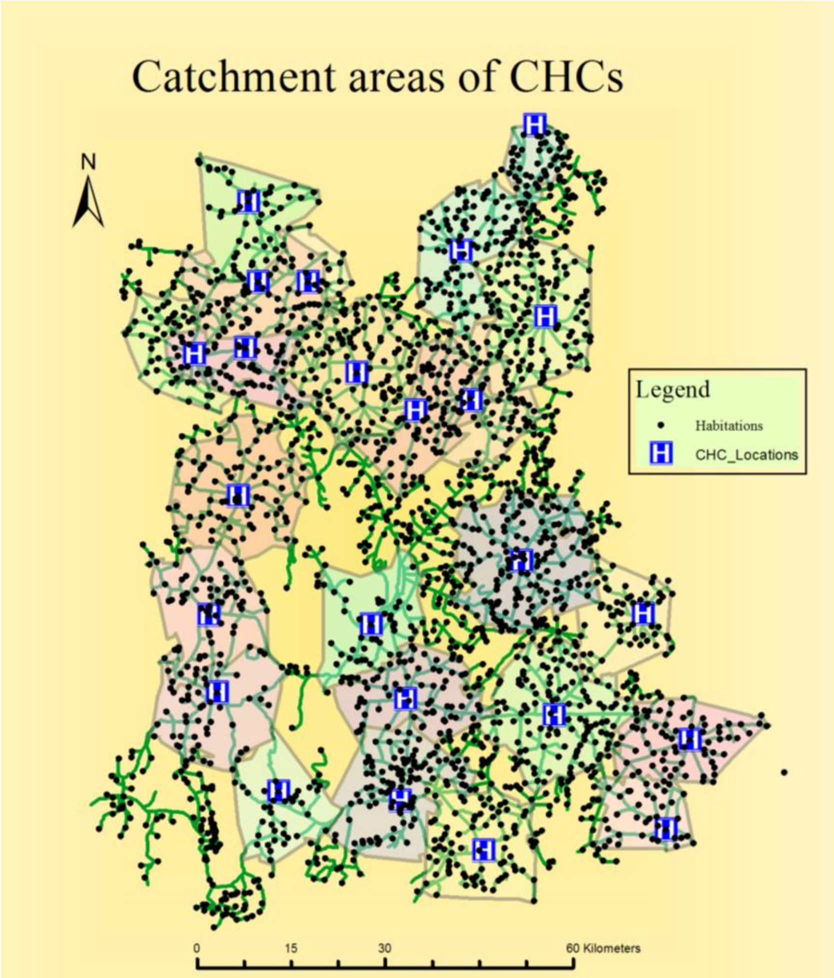


Fig 6.2. Catchment areas of CHC in Alwar district

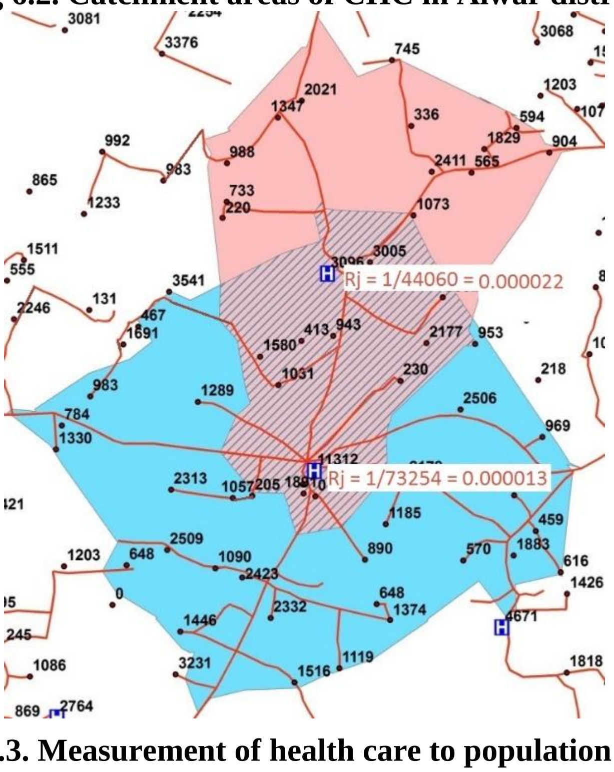


Fig .6.3. Measurement of health care to population ratio

The value of R_j has been calculated for all the health centers using a code developed in MATLAB (*Appendix 5)*. The format for input is shown in Table 6.1. For the purpose of easy identification, each CHC facility and habitation has been provided IDs. F is the weight for unpaved road length to be traveled by population to reach CHC. The calculated R_j values for all the districts are shown in Table 6.2. Since the denominator is extremely high compared to the numerator, the R_j value is very low. To make the values to be easily understood and thus to compare, they have been multiplied by 10^6. From the table 6.2 it can be observed that Bajju CHC of Bikaner district has higher health care to population ratio since the total population falling under the catchment area is very less when compared to others.

Table 6.1. Sample Input data for MATLAB

S.No	FacilityID	HabitaionID	Travel distance	Population	F_i
1	3	11	13.31	2297	1.00
2	3	30	14.09	1297	1.00
3	3	31	13.1	1418	0.89
4	3	32	12.07	2209	0.89
5	3	34	8.94	1591	1.00
6	3	35	10.43	1800	0.56
7	3	36	14	1018	0.08
8	1	37	13.8	803	0.73
9	1	45	8.92	1077	0.65

Table 6.2. Health care to population ratio of the CHCs using 2SFCA method

District	CHC location	Total population under catchment area	R_j	R_j (in 10^6)
Alwar	Behror	121232	8.25E-06	8.25
	Bardod	94293	1.06E-05	10.61
	Bansur	103347	9.68E-06	9.68
	Kherli	69256	1.44E-05	14.44
	Kathumar	79089	1.26E-05	12.64
	Kishangarh	100473	9.95E-06	9.95
	Khairthal	94978	1.05E-05	10.53
	Kotkasim	83081	1.20E-05	12.04
	Laxmangarh	116561	8.58E-06	8.58
	Govindgarh	48074	2.08E-05	20.80
	Mala Khera	103726	9.64E-06	9.64

District	CHC location	Total population under catchment area	R_i	R_i(in 10^6)
Alwar	Umren	42156	2.37E-05	23.72
	Mundawar	108275	9.24E-06	9.24
	Rajgarh	76673	1.30E-05	13.04
	Tehala	19025	5.26E-05	52.56
	Ramgarh	111739	8.95E-06	8.95
	Reni	59956	1.67E-05	16.68
	Shahajanpur	81701	1.22E-05	12.24
	Neemrana	129896	7.70E-06	7.70
	Thanagazi	56607	1.77E-05	17.67
	Narayanpur	70447	1.42E-05	14.20
	Tijara	80504	1.24E-05	12.42
	Bhiwadi	53162	1.88E-05	18.81
	Mandhan	69207	1.44E-05	14.45
Bikaner	Deshnok	23104	4.33E-05	43.28
	Napasar	51257	1.95E-05	19.51
	Khajuwala	40451	2.47E-05	24.72
	Gajner	13483	7.42E-05	74.17
	Kolayat	16425	6.09E-05	60.88
	Bajju	6385	0.000157	156.62
	Nokha	18676	5.35E-05	53.54
	Panchu	12650	7.91E-05	79.05
	Lunkaransar	43596	2.29E-05	22.94
	Sri Dungargarh	29789	3.36E-05	33.57
	Mahajan	18524	5.40E-05	53.98
Tonk	Duni	42489	2.35E-05	23.54
	Todaraisingh	34474	2.90E-05	29.01
	Malpura	42157	2.37E-05	23.72
	Uniyara	25956	3.85E-05	38.53
	Newai	47729	2.10E-05	20.95
	Deoli	14978	6.68E-05	66.76
	Peeploo	35116	2.85E-05	28.48
Jhunjhunu	Bagar	79817	1.25E-05	12.53
	Mandawa	42956	2.33E-05	23.28
	Malsisar	57968	1.73E-05	17.25
	Bissau	30487	3.28E-05	32.8
	Chirana	54693	1.83E-05	18.28
	Udaipurwati	63585	1.57E-05	15.73
	GudhaGorji	95714	1.04E-05	10.45
	Chirawa	109838	9.10E-06	9.1

District	CHC location	Total population under catchment area	R_j	R_j(in 10^6)
Jhunjhunu	Buhana	112320	8.90E-06	8.9
	Khetri	41628	2.40E-05	24.02
	Nawalgarh	83850	1.19E-05	11.93
Churu	Singhana	109061	9.17E-06	9.17
	Bidasar	24035	4.16E-05	41.61
	DoodwaKhara	34602	2.89E-05	28.9
	Rajaldesar	28705	3.48E-05	34.84
	Rajgargh	48693	2.05E-05	20.54
	Ratannagar	39865	2.51E-05	25.08
	Salasar	36270	2.76E-05	27.57
	Sardarshahar	39105	2.56E-05	25.57
	Sandwa	18577	5.38E-05	53.83
	Taranagar	28171	3.55E-05	35.5
	Sujangarh	19167	5.22E-05	52.17
	Surajgarh	76971	1.30E-05	12.99

In the second step of 2SFCA method the accessibility of a habitation has been calculated by following similar steps as in step 1 by using the closet facility tool in GIS. Here a particular village search for the health centers falling within their respective catchment area, i.e., acceptable distance (15 km) and sums up the health care to population ratios of the health centers. The accessibility of a village, A_i is the sum of R_j multiplied by the weight for the travel on unpaved road falling within the catchment area of the village. For the same example illustrated in step 1, the accessibility of a habitation A_i is calculated by summing up both the ratios of the health centers, falling within the habitation catchment area as shown in Fig. 6.4. It has been considered that accessibility is also the function of the kind of road as it would affect the travel time and comfort level. The weights for the unpaved road length to be travelled to reach health center by each habitation are also calculated. If the weight value is 1 it indicates that the total road length to be travelled by the habitation is a paved road. Lower weight indicates more travel on unpaved roads. In other words, the higher the travel on unpaved road, lower the accessibility. For example, in table 6.3, it may be observed that as the rate of the length travelled on the unpaved roads increases the weight accordingly increases moderately. The weights are calculated using 15 km as the maximum threshold distance of travel. Using the R_j and weights, accessibility is calculated. Likewise accessibility of all the habitations is computed for all the five districts. The sample results are shown in Table

6.4. Since the denominator is extremely high compared to the numerator, the A_i value is extremely low. To make the values to be easily understood and comparable, they have been multiplied by 10^6.

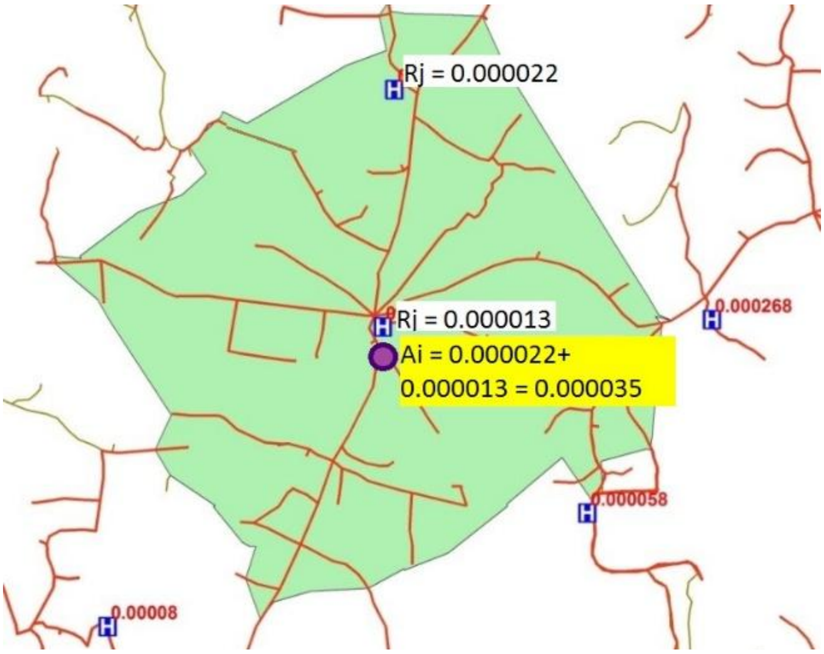


Fig . 6.4. Measurement of Accessibility of a habitation

Table 6.3. Weights for unpaved roads

Total road length	Unpaved road length	Weights
9.31	2.10	0.86
10.71	1.20	0.92
14.87	5.00	0.67
7.99	0.00	1.00
9.39	1.30	0.91
14.03	3.30	0.78
5.41	0.00	1.00
10.62	0.00	1.00
11.97	1.30	0.91
6.37	5.00	0.67
13.34	2.50	0.83
13.47	0.00	1.00
6.99	1.60	0.89
12.34	0.00	1.00

Table 6.4. Accessibility of habitations using 2SFCA method

HabitationID	Unpaved road length	F_i	A_i(in 10^6)
1	1.02	0.93	9.02
2	0	1.00	9.68
3	0	1.00	9.68
4	1.02	0.93	9.02
5	0	1.00	9.68
6	0	1.00	9.68
7	0	1.00	9.68
8	0	1.00	9.68
9	1.06	0.93	9.00
10	0	1.00	9.68
11	0	1.00	9.68
12	0	1.00	0.00
13	0	1.00	0.00
14	0	1.00	10.61
15	0	1.00	0.00
16	0	1.00	0.00
17	0.83	0.94	10.02
18	0	1.00	10.61
19	0	1.00	10.61

In this study 15 km of threshold distance has been used to find the habitations served by the CHC for all the districts. It has been noticed that as the population density decreases people are forced to travel for more than 15km to get the service. However, in this study all the habitations beyond 15km were considered as inaccessible to the CHC. From table 6.5, it can be noted that as the population density decreases, the percentage of population which do not have access increases. In Bikaner district 88.41% of the population do not have access to CHC. It has also been observed that all the inaccessible villages either do not have road connectivity or they are located far away from health centers. The total number of habitations served by CHC in all the districts are shown in table 6.

Table 6.5. Percentage of inaccessible habitations

District	Total population	Population density	Number of CHC	Average population served by a CHC	Population served by the catchment area	Percentage of population does not have access
Alwar	3671999	438	24	82227	1973458	46.26
Jhunjhunu	2139658	361	13	73760	958888	55.18
Tonk	1421711	198	7	34699	242899	82.92
Churu	2041172	148	10	31719	317190	84.46
Bikaner	2367745	78	11	24940	274340	88.41

Table 6.6. Total number of habitations served by the catchment area

S.No	District	Total number of habitations	Total number of habitations served by the catchment area
1	Alwar	2217	1578
2	Jhunjhunu	854	496
3	Tonk	1003	298
4	Churu	852	229
5	Bikaner	849	169

As per Indian Public Health Standards (IPHS), a CHC is set up in a location to serve about 1, 20,000 people in plain areas and 80,000 people in hilly, desert and other difficult areas. The averaged population served by CHCs in all the districts is less than the population norms mentioned by IPHS if the distance norm is considered as 15km. Thus there is scope to optimize the location of CHCs so that it could serve the maximum number of people. To provide uniform accessibility to all the habitations, number of CHCs should be increased in all the districts. In general, as the population density decreases, the more is the distance people need to travel to get the service. The maximum distances from which individuals are going to get the service in all the districts are found from the data collected from the register of CHCs. A proforma was prepared to collect the data as shown in *Appendix 2.* The detailed data regarding the habitations from where the patients were visiting the CHCs were collected from the register maintained by the CHCs. The travel distance of the habitations was also collected. It has been observed that in Bikaner district, people are travelling as high as 35 km to get the CHC service. The maximum distances from which a sizeable number of patients visiting the CHCs for all the districts are shown in Table 6.7. It was observed that sometimes a small number of patients were travelling more than the distance shown in the table 6.7. However, they were considered outliers.

Table 6.7. Maximum travel distances to reach CHC

District	Population density	Distance in km travelled to get service
Alwar	438	20
Jhunjhunu	361	23
Tonk	198	26
Churu	148	27
Bikaner	78	35

From the results obtained for all the districts, it has been observed that the maximum accessibility Index was found in Bikaner district and minimum was found in Alwar district (Table 6.8). The reason behind this trend is, as the population served within the catchment area of CHC is decreasing the population density is increasing i.e., the R_j value is higher. In other words, the lesser the number of the population to share a CHC, higher the R_j value and in turn higher the accessibility. However, in the low population density areas, the proportion of the population having no access to health care is normally high.

Table 6.8. Maximum Accessibility Index found in each district using 2SFCA

District	Average population served by a CHC	Maximum Ai using 2SFCA
Alwar	82227	52.6
Jhunjhunu	73760	56.08
Tonk	34699	66.76
Churu	31719	94.15
Bikaner	24940	156.62

The villages having accessibility were then classified into five groups depending on the Accessibility Indices using mean (10.80) and the standard deviation (9.59) as shown in Fig.6.5. Larger the size of the circle, more is the accessibility of the habitation. The villages having zero accessibility value indicates no access to health care centers, i.e., there are no CHCs within 15 km road distance from these habitations.

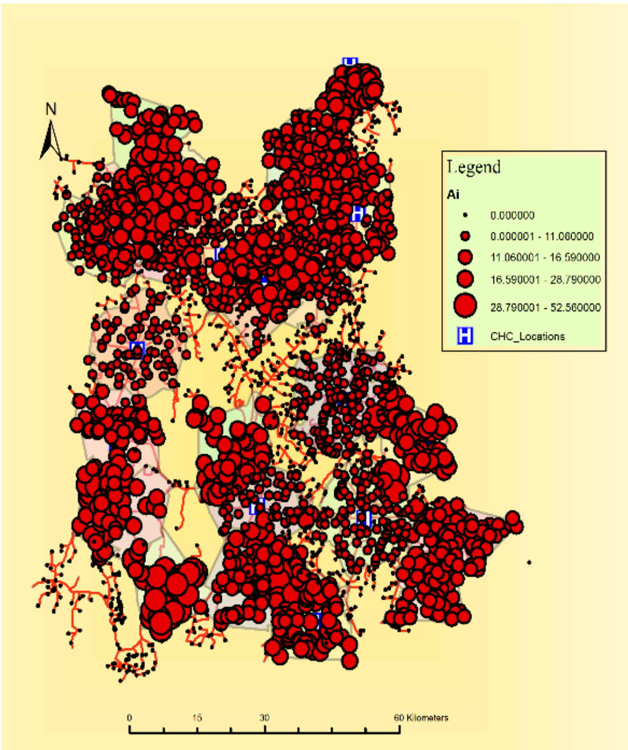


Fig.6.5. Accessibility Index of habitations for Alwar district

6.2.1 Statistical Validation

To verify the accuracy of the accessibility values obtained using 2SFCA method, a survey was conducted by asking habitants their satisfaction on the present accessibility level to CHC. The habitants selected for the survey were sampled from different socioeconomic backgrounds. The opinions were collected on 1 to 5 scale, where 5 meant highly satisfied, 4-satisfied, 3-undecided, 2-dissatisfied and 1- highly dissatisfied. The final value has thus been obtained on a scale of 1-5.

The predicted or calculated accessibility values from the 2SFCA method were converted into 1 to 5 scale for the comparison to the observed accessibility value. The class interval for all the predicted accessibility data has been calculated by subtracting the maximum extent value and the minimum extent value in the group of data. Then the class interval has been divided by 5, to obtain class interval range and then the ungrouped data are grouped into 5 classes. Then all the accessibility values have been converted to 1 to 5 scale. To check the statistical validity, paired sample t-test has been conducted for 95% confidence interval. The t-test was conducted using Statistical Package for the Social Sciences (SPSS) software. The p-value obtained should be more than 0.05 to prove that there is no significant difference between the predicted and observed values. But it has been observed that in all the five districts the value is less than 0.05, which indicates that this method does not simulate the actual accessibility levels of the villagers. The reason behind the failure of this method to simulate actual accessibility levels in rural areas is that accessibility is not only dependent on supply and demand but also quality of supply and mobility. Moreover, the habitations within the catchment are not differentiated based on their travel distance, i.e., the distance impedance within the catchment area is not considered.

Moreover, mean absolute percentage error (**MAPE**) has also been calculated to measure accuracy of the method used. The percentage error in all the districts is more than 10 %, which again indicates significant difference between two groups of data. The sample of MAPE calculation for Alwar district is shown in Table 6.9.

Table 6.9. Mean Absolute Percentage Deviation of accessibility (Alwar district)

S.No	Observed accessibility	Predicted accessibility	Absolute % of error
1.	1	1	0
2.	1	1	0
3.	1	1	0
4.	1	1	0
5.	2	1	50
6.	1	1	0
7.	2	1	50
8.	2	1	50
9.	1	1	0
10.	2	1	50
11.	3	2	33.33
12.	2	3	50
13.	3	1	66.67
14.	1	1	0
15.	3	1	66.67
16.	4	2	50
17.	3	1	66.67
18.	4	1	75
19.	4	1	75
20.	4	2	50
Mean absolute percentage error (**MAPE**)			**31.88435**

6.3. Enhanced Two-Step Floating Catchment Area Method (E2SFCA)

Luo (2009) worked on the limitation of 2SFCA method and proposed an enhanced two-step floating catchment area (E2SFCA) method in recent times. In order to differentiate accessibility within a catchment area different decay functions were being used. From literature, it has been noted that the distance friction parameter in the impedance function is estimated based on the travel behaviour of the people.

The method is implemented in two steps similar to 2SFCA method, in the first step health care to population ratio is calculated by considering the travel friction between the health care and population. In the second step a particular habitation search for the health centers falling within their respective catchment area, i.e., acceptable distance (15 km) and sums up the product of health care to population ratios of the respective health center, travel friction weight and weight on the proportion of the unpaved road length travel to reach the health center.

Step 1 : Health centre (HC) to population (P) ratio is calculated using Eq 6.3.

$$R_j = \frac{HC_j}{\sum_i P_i * f(d_{ji})} \tag{6.3}$$

Where,

P_i Population in habitation i

HC_j Number of health centers at j

d_{ij} the travel distance between i and j

R_j health care to population ratio at location j whose centroid falls within the catchment

Step 2: Accessibility Index of population

$$A_i = \sum_j R_j * f(d_{ij}) * F_j \tag{6.4}$$

$$F_j = \frac{d_m - d_{ij}}{d_m}$$

Where,

A_i the accessibility of the population at a given location i to health care based on the two step floating catchment area method.

R_j health care to population ratio at location j whose centroid falls within the catchment

$f(d_{ij})$ Impedance function

d_{ij} the distance travelled on the Unpaved road between habitation location i and Health center j

d_m Maximum threshold travel distance

F_j Weightage for travelling on unpaved road to reach health center j

Impedance function has been found by fitting from the data of trip length of patients visiting to the health centers and volume of interactions. From the function the constants have been calibrated and used to find the weights which are functions of travel distance.

The consideration of distance decay in the E2SFCA method is a reasonable approximation to the continuous gravity model. This approximation makes the result of the E2SFCA method straightforward to interpret and easy to use, because it is essentially a weighted health care-to-population ratio.

6.3.1 Calibration of Impedance function

In order to differentiate accessibility within a catchment different decay function are used in E2SFCA Method. From literature, it has been noted that ideally the distance friction parameter in the impedance function is estimated based on the revealed travel behaviour of the patients.

From the data collected on the trip length of different villagers visiting the health centers and frequency of interaction, impedance function has been calibrated. The data has been collected from all the CHCs of the selected blocks. The distance of travel and the volume of interactions between them has been plotted as shown in figure 6.6. From the scatter plot it might be observed that with distance the number of patients visiting a health centre decreases gradually. It has been observed from the plots of different districts that people are forced to travel for more than 15 km to get the service, especially in Bikaner and Churu districts where population density is less. However, habitations are considered inaccessible if they are travelling beyond the threshold distance of 15 km in all the districts. Also in this study all the patients travelling a distance of less than or equal to 1 km has been given a weight of 1 as the villagers normally do not feel any impedance in travelling within this distance. Also, they do not expect to have a facility such as CHC very close to their residents.

The average of patients visiting per day are normalized in the scale of 0 to 1 with respect to the maximum value in the series through a simple normalization using Eq 6.5. The distance of the village from the health center and the normalized average, patients visiting per day for the corresponding village have been plotted to find the travel pattern in that area.

$$\text{Normalized value} = \frac{x_{ji}}{\max(x_{ji})} * 100 \qquad (6.5)$$

Where,

x_{ji} is the extent of a criteria

Max (x_{ji}) is the maximum extent value

For all the districts, data have been collected from all the CHCs located in the selected blocks. From the data sheet, the average patients visiting CHC per day from each village have been computed. In all the districts at least 40 data points were obtained for the analysis. The outliers in the data have been detected using SPSS software. The reason for the outliers in the data may be due to the occasional visit by the patients to the CHC for some specific reasons.

By capturing the trend in the data by assigning a single function across the entire range and by using the method of regression analysis the best fit curves have been plotted for all the five districts. CurveExpert professional 2.2.0 software has been used to fit a nonlinear regression. The results obtained from the calibration exercise for all the five districts are shown in Table 6.10. In the table weight (y) has been obtained as the function of travel distance (x). The non-linear regression equations fitted to the data and their corresponding constants and R^2 also have been presented in table 6.10. Additionally to check the robustness of the models, the Analysis of Variance (ANOVA) and Standard Error of Estimate (SEE) were calculated and were found to be significant and within the acceptable limits for all the models.

Table 6.10. Impedance functions

District	Non-Linear regression	Model	Equation	Constant value	R^2
Alwar	Logistic power	Sigmoidal	$y = \frac{a}{\left(1+\left(\frac{x}{b}\right)^c\right)}$	a = 6.83 b = 9.72 c = 4.48	0.821
Tonk	Morgan-Mercer Flodin (MMF)	Sigmoidal	$y = \frac{ab+cx^d}{b+x^d}$	a = -9.91×10^{-2} b = 5.70×10^{-9} c = 9.92×10^{-1} d = -7.87	0.868
Jhunjhunu	Logistic power	Sigmoidal	$y = \frac{a}{\left(1+\left(\frac{x}{b}\right)^c\right)}$	a = 9.93×10^{-1} b = 9.535 c = 5.021	0.962

District	Non-Linear regression	Model	Equation	Constant value	R^2
Churu	Hyperbolic Decline	Decline	$y = q_o\left(1+\frac{bx}{a}\right)^{\left(\frac{-1}{b}\right)}$	$q_o = 9.88\times10^{-1}$ a = 33.48 b = -2.126	0.874
Bikaner	Rational Model	Miscellaneous	$y = \frac{a+bx}{1+cx+dx^2}$	a = 1.047 $b = -6.77\times10^{-2}$ $c = 1.286\times10^{-2}$ $d = -4.26\times10^{-3}$	0.914

In this study it has been observed that the influence of population between the two places was inversely proportional to the distance between them (inverse distance weighting function). The same trend was also reported by Stewart (1941). In general, inverse power and negative exponential distance weighting functions were used as spatial interaction models in the past studies. The constants represent travel friction in all the models. But as a contrary in this study, data have not been fitted well to the commonly used inverse power and negative exponential functions. However, as Guy (1983) and Kwan (1998) pointed out, these two impedance functions decline too steeply close to the trip origin and produce unrealistic accessibility patterns. As shown in Fig. 6.6, Fig 6.7 and Fig 6.8, the Logistic power and MMF measure, resembling the bump-shaped, sigmodial distribution curve, drops very gradually at first, then more abruptly as the distance increases from origin. In the graphs, X-axis, d is the travel distance of habitations from CHC and Y-axis, f(d) is the weight calculated from the calibrated impedance function which is a function of distance. The Y-axis represents the normalized volume of interactions. It appears that these functions are most appropriate in the context of densely populated regions as in Alwar, Jhunjhunu and Tonk districts. Whereas in the Fig 6.9, it shows hyperbolic decline, the curve drops continuously from the first as the distance increases from the origin. Similarly, in rational model (Fig 6.10) also curve drops continuously as the distance increases, but the y value, i.e., the weightage value is high at the maximum distance (15km), when compared to hyperbolic decline. The reason behind this is in the places of lower population density like Bikaner and Churu, people are captive and are travelling long distance to get the service. Additionally the number of CHCs is also low. In a generalized form it can be stated that sigmoidal functions like logistic power and MMF are more likely suitable for the high population density regions and also plain terrains, whereas decline functions and rational models can be used for low population density regions and difficult desert or hilly areas.

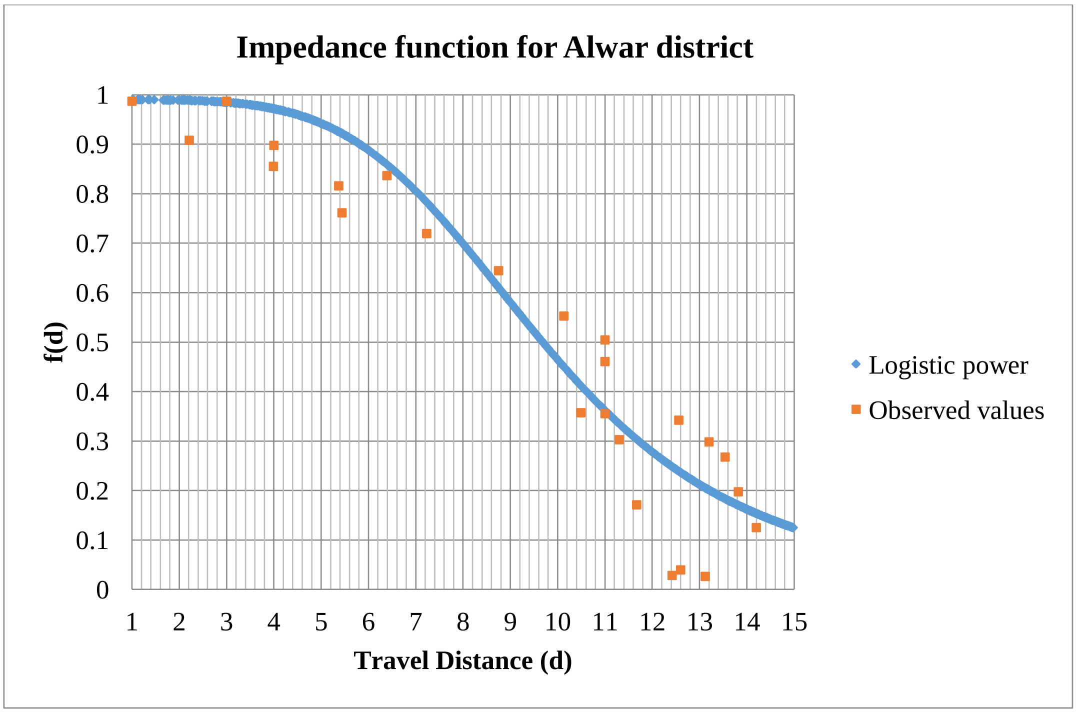


Fig. 6.6. Impedance function for Alwar district

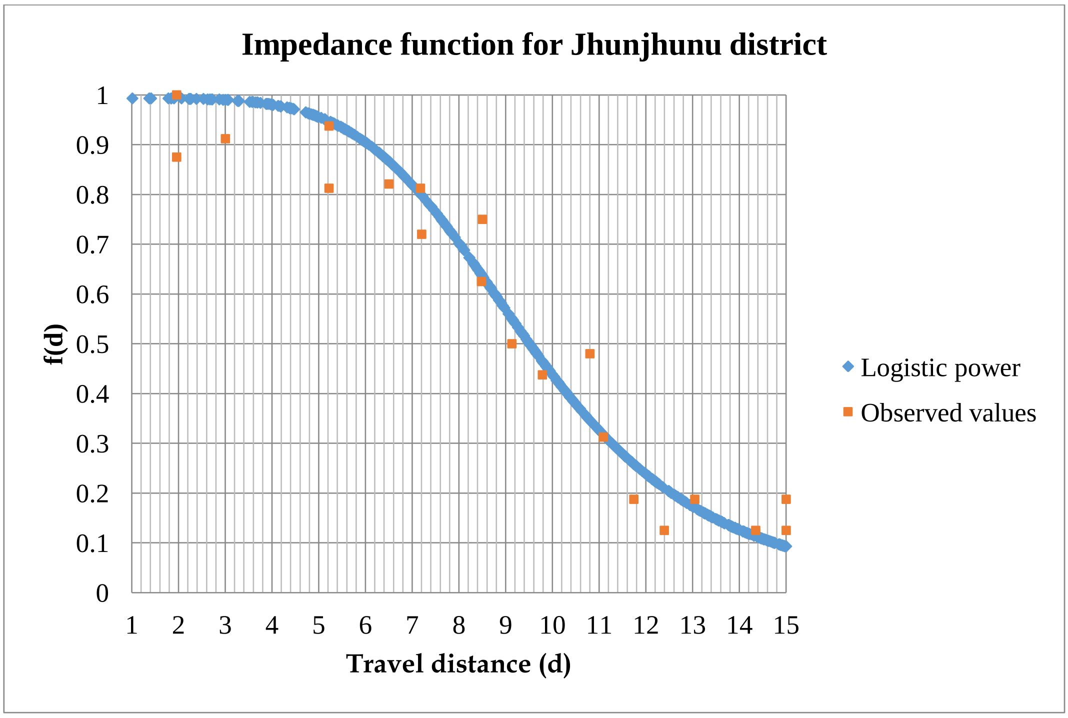


Fig. 6.7. Impedance function for Jhunjhunu district

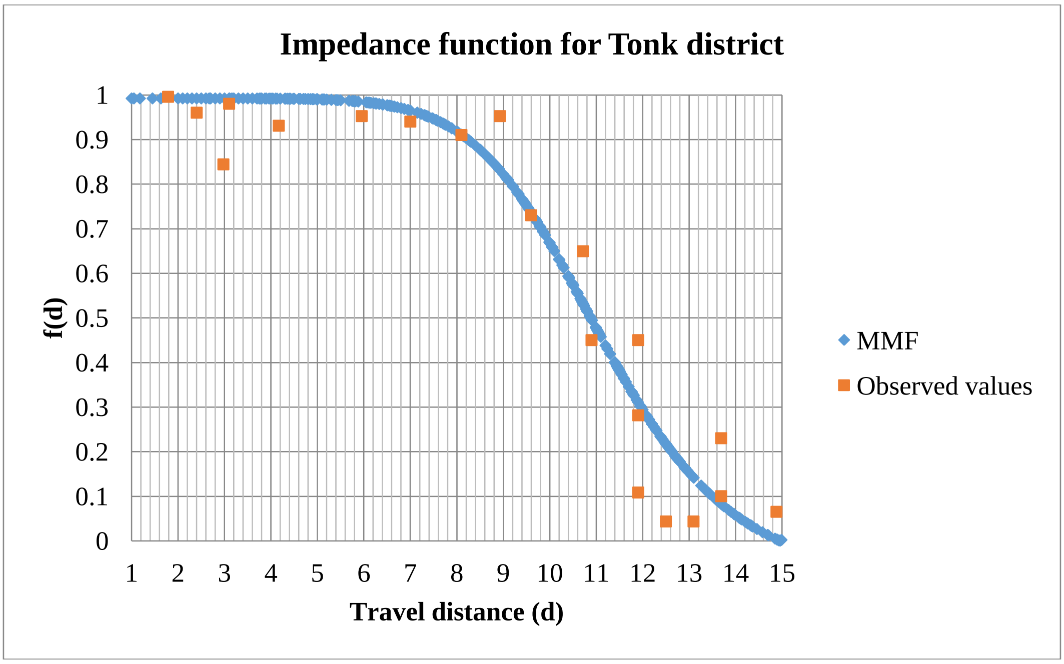


Fig. 6.8. Impedance function for Tonk district

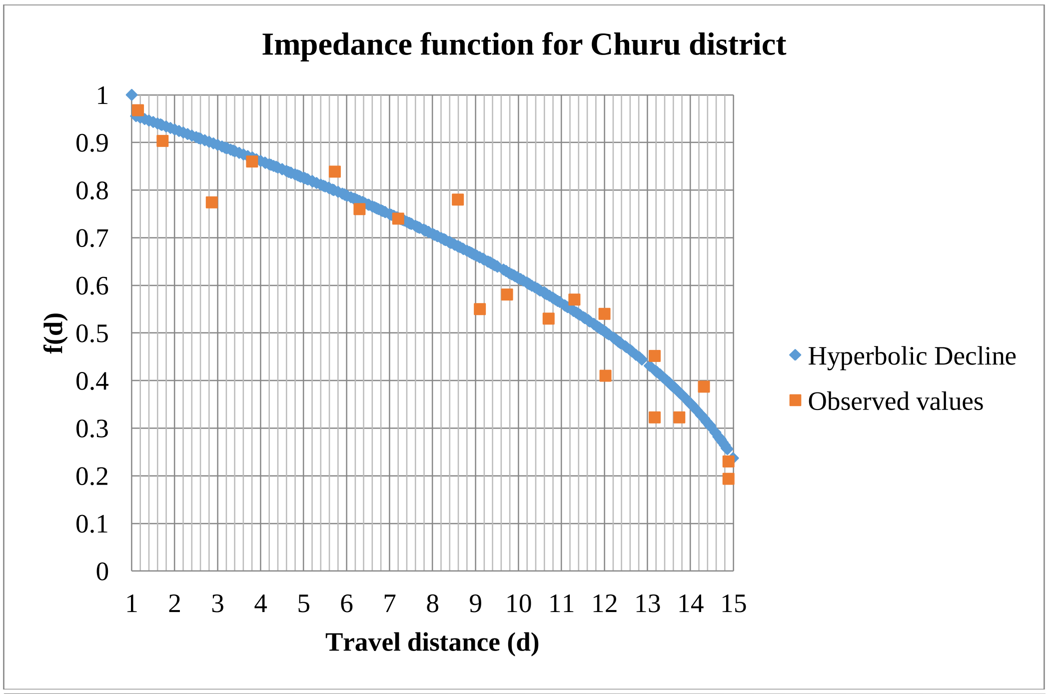


Fig. 6.9. Impedance function for Churu district

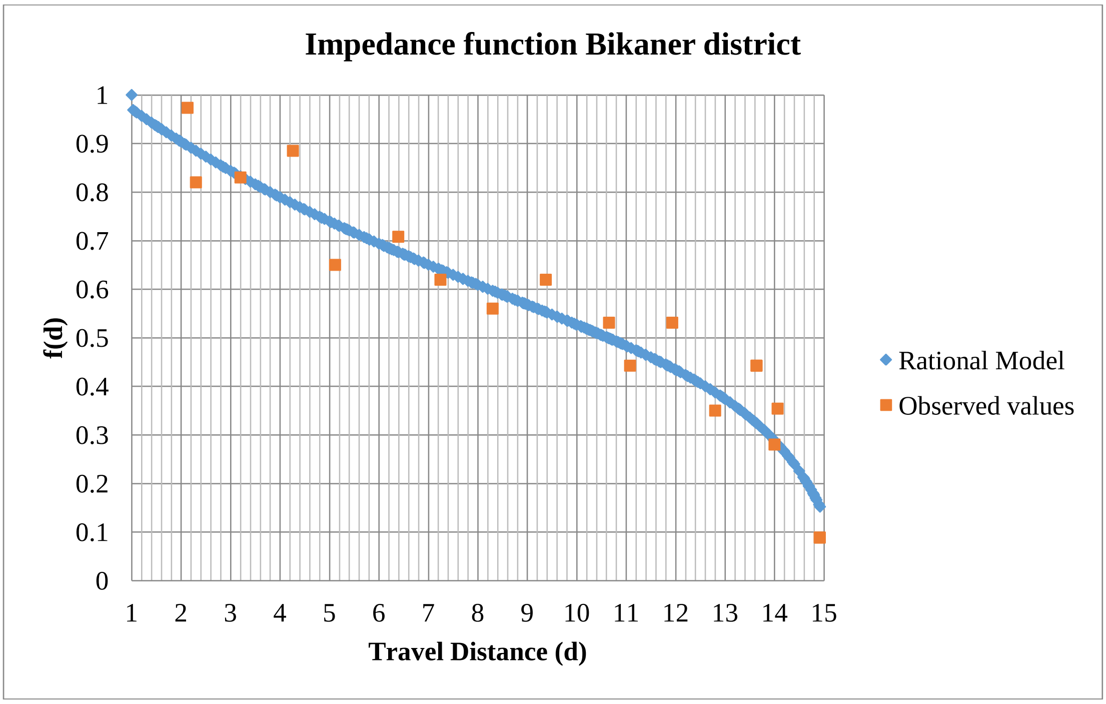


Fig. 6.10. Impedance function for Bikaner district

6.3.1.1 Statistical validation of Impedance function

Data on the randomly 70% of the observed values was used for developing impedance function and the remaining 30% of the observed values was kept aside for the model validation. The deviation between the observed normalized average number of patients per day and the predicted normalized average number of patients visiting per day (Weights) was calculated. Percentage of deviation or error has been calculated using the Eq. 6.6.

$$\text{Percentage of Deviation} = \left| \frac{Observed(W) - Predicted(W)}{Observed(W)} \times 100 \right| \qquad (6.6)$$

It may be observed from Table 6.11 that there is not much variation between the weight values with those of the predicted values using individual and generalized equations. The Mean Absolute Percentage Deviation (MAPD) of the values with the developed individual and equations from those of the observed values are ranging from 6.21 to 2.89 respectively. Generally, an average deviation value less than 10 % is acceptable. Thus the equations have been found to be satisfactory for predicting weight values.

Table 6.11. Mean Absolute Percentage Deviation of travel friction weights

District	Distance from CHC (in Km)	Observed values	Predicted values	Absolute % of error	Mean Absolute Percentage Deviation (MAPE)
Alwar	9.76	0.45	0.49	8.89	6.21
	5.88	0.86	0.90	4.65	
	7.78	0.66	0.72	9.09	
	3.24	0.93	0.98	5.38	
	1.34	0.94	0.99	5.32	
	1.81	0.93	0.99	6.45	
	4.43	0.85	0.96	12.94	
	1.77	0.90	0.99	10.00	
	0.90	1.00	0.99	1.00	
	5.34	0.98	0.93	5.10	
	4.23	0.92	0.97	5.43	
	6.16	0.86	0.88	2.33	
	5.29	0.93	0.93	0.00	
	7.74	0.65	0.73	12.31	
	8.25	0.70	0.67	4.29	
Tonk	7.89	0.91	0.93	2.20	4.14
	13.63	0.08	0.09	12.50	
	7.35	0.92	0.95	3.26	
	7.00	0.93	0.96	3.23	
	4.42	0.98	0.99	1.02	
	7.49	0.94	0.95	1.06	
	8.29	0.91	0.90	1.10	
	12.98	0.13	0.16	23.08	
	4.48	0.98	0.99	1.02	
	6.50	0.96	0.98	2.08	
	8.76	0.83	0.85	2.41	
	7.23	0.95	0.96	1.05	
	5.30	0.96	0.99	3.13	
	9.21	0.76	0.79	3.95	
	10.66	0.55	0.54	1.82	
Jhunjhunu	8.77	0.60	0.60	0.00	3.79
	14.11	0.10	0.12	20.00	
	12.86	0.19	0.18	5.26	
	12.18	0.23	0.22	4.35	
	9.87	0.46	0.45	2.17	
	8.05	0.71	0.70	1.41	
	9.58	0.48	0.49	2.08	
	9.54	0.48	0.50	4.17	
	12.49	0.21	0.20	4.76	
	14.25	0.13	0.12	7.69	

District	Distance from CHC (in Km)	Observed values	Predicted values	Absolute % of error	Mean Absolute Percentage Deviation (MAPE)
Churu	13.61	0.36	0.39	8.33	2.89
	11.07	0.51	0.56	9.80	
	9.03	0.65	0.66	1.54	
	8.04	0.72	0.71	1.39	
	11.75	0.52	0.52	0.00	
	10.04	0.60	0.61	1.67	
	7.47	0.71	0.73	2.82	
	9.28	0.66	0.65	1.52	
	7.17	0.72	0.74	2.78	
	10.38	0.58	0.60	3.45	
	7.51	0.71	0.73	2.82	
	8.43	0.67	0.69	2.99	
	7.26	0.73	0.74	1.37	
	10.22	0.61	0.60	1.64	
	6.74	0.75	0.76	1.33	
Bikaner	10.71	0.51	0.50	1.96	3.01
	14.27	0.25	0.26	4.00	
	12.37	0.45	0.41	8.89	
	12.41	0.42	0.41	2.38	
	9.03	0.59	0.57	3.39	
	12.96	0.40	0.38	5.00	
	13.42	0.33	0.34	3.03	
	13.96	0.28	0.29	3.57	
	5.03	0.72	0.74	2.78	
	0.00	0.99	1.00	1.01	
	6.22	0.67	0.68	1.49	
	5.75	0.71	0.71	0.00	
	10.19	0.50	0.52	4.00	
	8.59	0.57	0.58	1.75	

After calculation of travel friction factors, similar steps have been followed as done in 2SFCA method. Same outputs from the GIS analysis as in earlier method have been used in this method too. Additionally, distance data have been used as input in the impedance functions and the corresponding weights for all the habitations have been calculated in excel. By including the weights for travel distance and weights for unpaved roads the MATLAB program has been modified. The details of the program are shown in *Appendix 6*. The sample inputs used in MATLAB are shown in Table 6.12. For example, in Table 6.12, serial no 1, HabitationID 11 falls within the catchment area of FacilityID 3 and the distance between them is 13.31km and the population of habitationID 11 is 2297 and there is no unpaved road to be travelled. And the travel friction weight (0.351) is calculated using the equations modelled and presented in table no 6.10. Similar to 2SFCA method accessibility values have been multiplied by 10^6. The R_j values of Alwar district are shown in the Table 6.13.

Table 6.12. Inputs for MATLAB (E2SFCA method)

S.No	FacilityID	HabitaionID	Travel distance	Population	F_j	$f(d_{ij})$
1	3	11	13.31	2297	1.00	0.351
2	3	30	14.09	1297	1.00	0.278
3	3	31	13.1	1418	0.89	0.367
4	3	32	12.07	2209	0.89	0.431
5	3	34	8.94	1591	1.00	0.571
6	3	35	10.43	1800	0.56	0.509
7	3	36	14	1018	0.08	0.288
8	3	37	13.8	803	0.73	0.309
9	3	45	8.92	1077	0.65	0.571
10	3	46	10.31	1257	0.65	0.514

Table 6.13. Health care to population ratio of CHCs (E2SFCA method)

FacilityID	CHC location	Total population under catchment area	Rj	Rj (in 10^6)
1	Behror	70072	1.43E-05	14.27
2	Bardod	40983	2.44E-05	24.4
3	Bansur	66206	1.51E-05	15.1
4	Kherli	46701	2.14E-05	21.41
5	Kathumar	54976	1.82E-05	18.19
6	Kishangarh	53787	1.86E-05	18.59
7	Khairthal	49165	2.03E-05	20.34
8	Kotkasim	49216	2.03E-05	20.32
9	Laxmangarh	60069	1.66E-05	16.65
10	Govindgarh	32176	3.11E-05	31.08
11	Mala Khera	60310	1.66E-05	16.58
12	Umren	22633	4.42E-05	44.18
13	Mundawar	49980	2.00E-05	20.01
14	Rajgarh	43881	2.28E-05	22.79
15	Tehala	12625	7.92E-05	79.2
16	Ramgarh	50310	1.99E-05	19.88
17	Reni	37091	2.70E-05	26.96
18	Shahajanpur	46187	2.17E-05	21.65
19	Neemrana	59054	1.69E-05	16.93
20	Thanagazi	37514	2.67E-05	26.66
21	Narayanpur	39959	2.50E-05	25.03
22	Tijara	38311	2.61E-05	26.1
23	Bhiwadi	37063	2.70E-05	26.98
24	Mandhan	40523	2.47E-05	24.68

In 2SFCA method, the habitations falling under the catchment area of a health center have acquired same accessibility values. However, in this method by introducing the travel friction factor, accessibility levels have been differentiated within the catchment area. This can be observed from the sample results shown in Table 6.14. The accessibility values of the habitations within the catchment area of a particular CHC, say X, from the 2SFCA method and E2SFCA method are shown in Fig 6.11and 6.12 respectively. From the Fig 6.11 it can be noticed that in 2SFCA method all the habitations within the catchment area are having same accessibility values except for the habitations connected by unpaved roads. Whereas in E2SFCA method for the same X CHCs catchment area there is differentiation in the accessibility values with respect to distance from CHC. The same differentiation is shown in the Table 6.14, for example for the habitations 5 to 8, the accessibility value is 9.68 as per 2SFCA method, but when the accessibility is recalculated for the same set of habitations using E2SFCA method the values varied based on the travel distance within a range of 10.9 to 15.4.

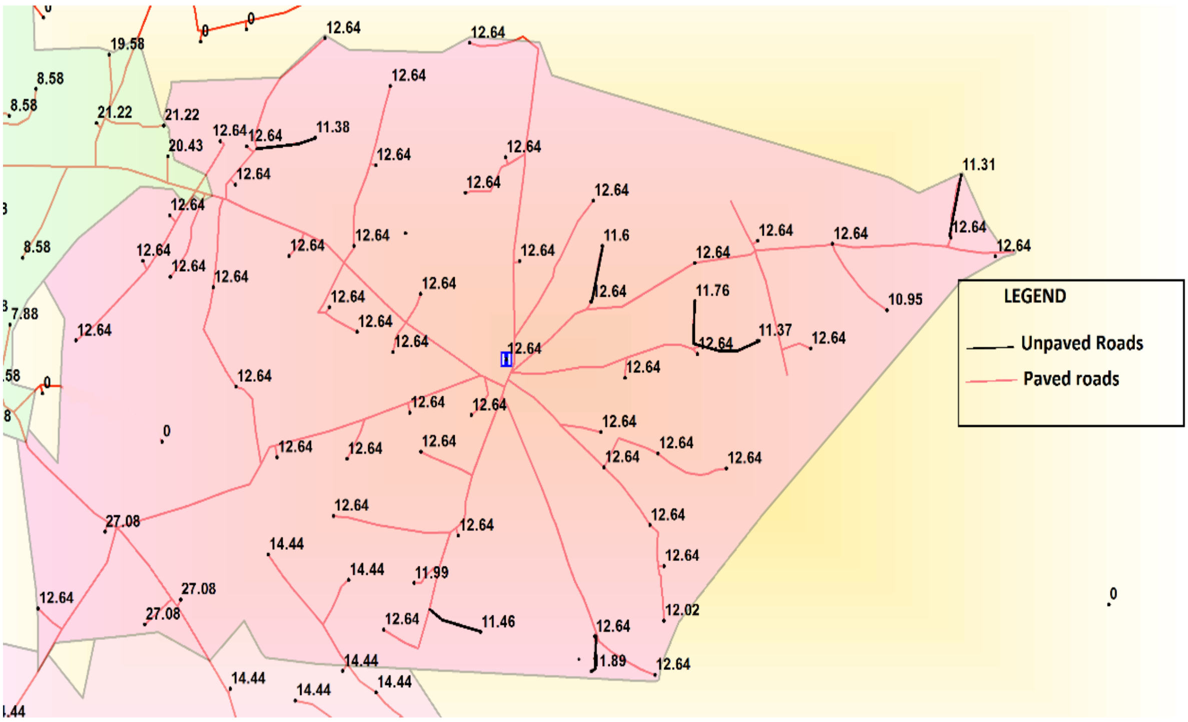


Fig. 6.11. Accessibility Index of habitations (2SFCA method)

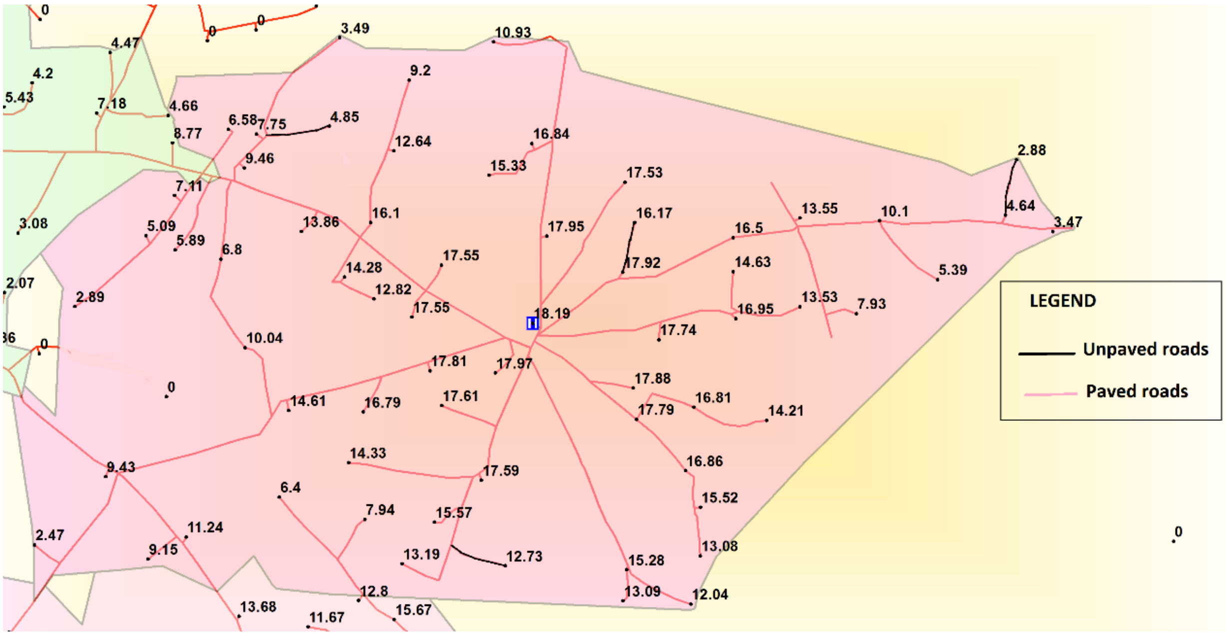


Fig. 6.12. Accessibility Index of habitations (E2SFCA method)

Table 6.14. Comparison of Accessibility Index calculated using 2SFCA and E2SFCA methods

Habitation_ID	Travel Distance	$f(d_{ij})$	F_j	A_j (2SFCA)	A_j (E2SFCA)
1	5.03	0.989	0.93	9.02	4.69
2	6.56	0.962	1.00	9.68	6.56
3	8.76	0.989	1.00	9.68	8.76
4	9.62	1	0.93	9.02	8.97
5	10.94	0.929	1.00	9.68	10.94
6	14.85	0.728	1.00	9.68	14.85
7	14.53	0.3	1.00	9.68	14.53
8	15.0	0.148	1.00	9.68	15.10
9	13.25	0.276	0.93	9.00	12.31
10	14.03	0.162	1.00	9.68	14.03
11	11	0.135	1.00	9.68	11.00
12	19.1	0.595	1.00	0.00	0.00
13	22.3	0.672	1.00	0.00	0.00
14	3.05	0.48	1.00	10.61	3.05
15	18.6	0.595	1.00	0.00	0.00
16	17.5	0.413	1.00	0.00	0.00
17	3.76	0.173	0.94	10.02	3.55
18	6.73	0.397	1.00	10.61	6.73
19	3.95	0.52	1.00	10.61	3.95

6.3.2 Statistical validation

The observed values of accessibility as mentioned in the earlier method were used to validate this method. Again, the predicted or calculated accessibility values from the

E2SFCA method were converted into 1 to 5 scale for comparison with the observed accessibility value. To check the statistical validity, paired sample t-test has been conducted for 95% confidence interval. The t-test was conducted using Statistical Package for the Social Sciences (SPSS) software. The p-value obtained is again less than 0.05, but this time in some of the districts the values are closer to 0.01. This method shows better results over previous as it differentiates accessibility values of the habitations falling within the catchment area by assigning weights for travel distance. However the p values are insignificant, i.e., less than 0.05 which indicates that this method also does not reflect the actual accessibility levels of the villagers as it does not consider the quality of supply and mobility factors.

Moreover, mean absolute percentage error (**MAPE**) has also been calculated to measure accuracy of the methodology developed. The percentage error in all the districts is more than 10 %, which again indicates significant difference between two groups of data. The Mean Absolute Percentage of Deviation from the observed and predicted accessibility is shown in Table 6.15.

Table 6.15.Mean Absolute Percentage of Deviation of Accessibility (E2SFCA method)

S.No	**Observed accessibility**	**Predicted accessibility**	**Absolute % of error**
1.	1	1	0
2.	1	1	0
3.	1	1	0
4.	2	1	50
5.	1	1	0
6.	2	2	0
7.	2	1	50
8.	2	1	50
9.	3	1	66.67
10.	3	3	0
11.	2	1	50
12.	3	1	66.67
13.	1	1	0
14.	3	1	66.67
15.	4	1	75
16.	3	1	66.67
17.	4	1	75
18.	4	1	75
19.	4	1	75
Mean absolute percentage error (**MAPE**)			**35.50783**

6.4. Modified Two-Step Floating Catchment Area Method (M2SFCA)

During the process of data accumulation from CHC, it has been observed in the field that all the CHCs don't deliver the same quality of service and the travel behavior of the villagers change accordingly. In addition, a noteworthy parameter that influences the accessibility in developing countries is the mobility of the people. As individuals utilize distinctive modes of transport their accessibility level changes accordingly. Therefore, keeping the importance of the influence of the mode on accessibility it was decided to do habitation level mode wise analysis. Accessibility has been derived separately for the males and females as the opinion on the service provided by CHC was significantly different for both the genders. By this method also accessibility is calculated in two steps.

Step 1: Health center to population ratio including travel friction and weight on the quality of the health service provided is calculated (Eq. 6.7). The travel friction is calculated from the Impedance function modelled using travel behaviour data of the individuals. Quality of service is calculated by aggregating the present health care standards maintained by CHC and the opinion of the villagers on the quality of service provided by CHC.

$$R_j = \frac{HC_j * Q_j}{\sum_i P_i * f(d_{ji})} \tag{6.7}$$

$$Q_j = (W_1 * HSR_j) + (W_2 * V_j)$$

$$V_j = \frac{\sum_{k=1}^{N} \tilde{W}_k \otimes \tilde{R}_k}{\sum_{k=1}^{N} \tilde{W}_k}$$

$$HSR_j = \frac{\sum_{n=1}^{N} \left[\frac{D_n}{S_n} \right]}{N}$$

Where,

P_i Population in habitation i

HC_j Number of health centers at j

d_{ij} The travel distance between i and j

R_j health care to population ratio at location j whose centroid falls within the catchment

$f(d_{ij})$ Impedance function

Q_j Quality of service provided by the health center j

$W_{1,2}$ Weights assigned for the importance of the health care standard rating and Perception of the villagers on health center j

HSR_j Health care standard rating of health center j

D_n Scores of n parameters against the standards prescribed by Government

S_n Standard score prescribed by the Government on n parameters

$\otimes$ Fuzzy multiplication

$\tilde{W}$ Fuzzy weights assigned to the various factors

$\tilde{R}$ Fuzzy rating scores obtained by the corresponding factors

Step 2: Accessibility Index of the population is calculated using Eq. 6.8. In this step a particular village searches for the health centers falling within their respective catchment area and then sums up the product of health care to population ratios, travel friction weight, weight on the proportion of unpaved road length and the mobility of the respective mode. The mobility is calculated for different modes by taking into account the travel time and the travel cost of every mode separately.

$$A_i^m = \sum_j R_j * f(d_{ij}) * F_j * M_i^m \qquad (6.8)$$

$$M_i^m = \frac{\sum_{l=1}^{N} \tilde{W}_l \otimes \tilde{R}_l}{\sum_{l=1}^{N} \tilde{W}_l}$$

$$F_j = \frac{d_m - d_{ij}}{d_m}$$

Where,

A_i^m The accessibility of the population at a given location i to health care using mode m of transport.

R_j health care to population ratio at location j whose centroid falls within the catchment

$f(d_{ij})$ Impedance function

V_j Perception of villagers on health center j

$\otimes$ Fuzzy multiplication

$\tilde{W}$ Fuzzy weights assigned to the various factors

$\tilde{R}$ Fuzzy rating scores obtained by the corresponding factors

M_i^m Mobility of the habitation i using mode m

d_m Maximum threshold travel distance

d_{ij} the distance travelled on the Unpaved road between habitation location i and Health center j

F_j Weightage for travelling on unpaved road to reach health care

Various important steps involved in the quantification of accessibility using modified two step floating catchment area method are present in the form of a flow chart in Fig 6.13 and are discussed in detail in this chapter.

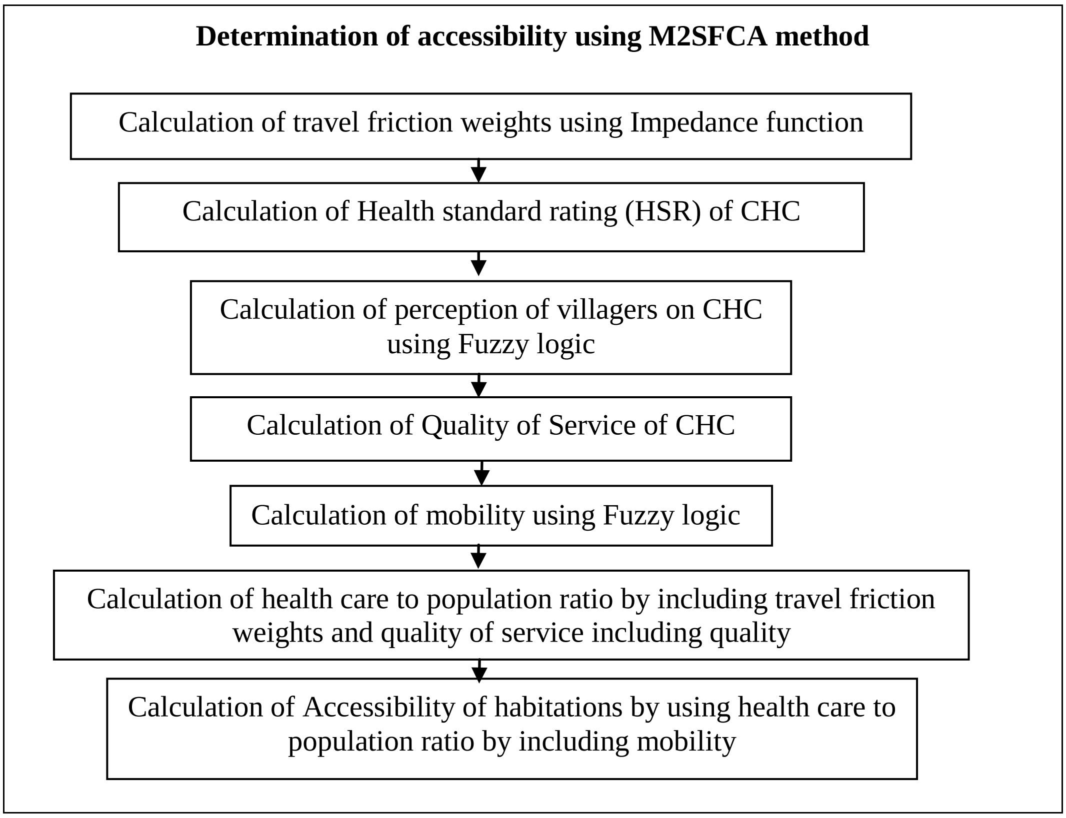


Fig. 6.13. Flow chart showing various steps involved in the calculation of accessibility using M2SFCA method

6.4.1 Determination of Impedance function

The weights for travel friction have been calculated using the non-linear regression equations fitted in between travel distance and normalized average number of patients visiting CHC (weights). The equations and constants calibrated and presented in Table 6.10 are used to find the weights. The input variable in the equation is the distance between CHC and habitation. Further the calculated weights are used as inputs in finding out accessibility.

6.4.2 Determination of Quality of Service

Q_j is the weight assigned to the quality of service provided by the health center j. During the process of data collection, it has been observed that all the CHCs do not deliver the same quality of service and the travel behavior of patients change accordingly. The quality of service is the function of two important parameters, health care standard rating (HSR) and the satisfaction of the villagers on the quality of service provided (V_j) such as availability of a physician, medicine, waiting time to get the service and the quality of the physician.

6.4.2.1 Determination of Health cares standard rating (HSR)

HSR in this study is calculated by taking the sum of the ratio of the present availability scores to the required standard, under five selected parameters from the list mentioned by Indian Public Health Standards (IPHS) (MHFW, 2012). The selected topics of the CHC format were clinical manpower, support manpower, physical infrastructure, service facilities and lab facilities. The formats were sub-divided according to major areas. The format used to evaluate the service offered by CHCs is shown in *Appendix 3.* Data was collected in all the functioning CHCs of the selected blocks in a district with the help of block health officials and NGOs. The respondent of the study was the person in charge of the CHC. The sample data for clinical manpower of a CHC are shown in Table 6.16. For physical infrastructure, facilities related to lab, data have been collected in binary form (i.e., 1 or 0), where, 1 represents availability and 0 unavailability of the facility. The sample data collected for lab facilities are shown in the Table 6.17.

Table 6.16. Sample data collected from CHC on Clinical Manpower

Community Health Centre			
S.No.	**Personnel**	**Clinical Manpower**	
		In position	**Required**
1	General Surgeon	0	1
2	Physician	1	1
3	Obstetrician / Gynaecologist	0	1
4	Paediatrics	1	1
5	Anaesthetist	0	1
6	Public Health Manager	1	1
7	Eye Surgeon	0	1
8	Dental Surgeon	1	1
S.No.	**Personnel**	**Clinical Manpower**	
		In position	**Required**
9	General Duty Medical Officer	1	2
10	Specialist of AYUSH	0	1
11	General Duty Medical Officer of AYUSH	0	1
	Total	5	12

Table 6.17. Sample data collected from CHC on lab facilities

S.No.	Lab Facilities	Yes	No
1	Availability of ECG currently at CHC	1	0
2	X-Ray facilities currently at CHC	1	0
3	Ultrasound facilities currently at CHC	0	1
4	Availabilities of specific lab test facilities	0	1

The required standards of each criteria and the present score of a CHC are shown in Table 6.18. The total aggregated ratios are normalized to the scale of 0 to 1 using Eq 6.5.

Table 6.18. Present score of CHC on standard criteria

S.No	Criteria	Standard required scores	Present score of CHC	Ratio
1	Clinical Manpower	12	2	0.17
2	Support Manpower	81	56	0.69
3	Physical Infrastructure	14	12	0.86
4	Service facilities	18	8	0.44
5	Lab Facilities	4	2	0.50
Total				2.66
Normalized value				0.53

In the event that the HSR value is 1 it implies that the health center has fulfilled all the standards being prescribed by the government to provide optimal care to the community. In the table 6.18, the value 0.53 indicates that the CHC1 has only 53% of the total acceptable standards for the delivery of the service it is designed for. Likewise HSR values for all the CHC in the blocks are calculated and shown in Table 6.19. The HSR values are ranging from 0.39 to 0.77. The highest quality of service provided in all the CHCs is at Surajgarh CHC in Jhunjhunu district.

Table 6.19. HSR value for CHCs

S.No.	CHC location	Block	District	HSR
1	Neemrana	Neermana	Alwar	0.44
2	Shahajapura	Neermana	Alwar	0.55
3	Mandhan	Neermana	Alwar	0.49
4	Behor	Behor	Alwar	0.50
5	Mundawan	Mundawan	Alwar	0.64
6	Buhana	Buhana	Jhunjhunu	0.53
7	Singhana	Buhana	Jhunjhunu	0.69
8	Surajgarh	Chirawa	Jhunjhunu	0.78
9	lunkransar	lunkransar	bikaner	0.67
10	Momasar	dungargarh	bikaner	0.40
11	Mahajan	lunkransar	bikaner	0.47
12	Sujangarh	sujangarh	churu	0.75
13	Ratangarh	ratangarh	churu	0.57
14	Rajaldesar	ratangarh	churu	0.58
15	Pipili	Pipili	Tonk	0.54
16	Newai	newai	Tonk	0.71
17	Unitap	Unitap	Tonk	0.64

6.4.2.2 Determination of Villagers opinion of health services provided

To find aggregated viewpoint of the villagers on the parameters such as availability of a physician, medicine, waiting time to get service and conduct of the physicians, fuzzy aggregation method has been used as parameters or indicators were collected using linguistic scale. The evaluations on the parameters are subjective in nature and thus there would be vulnerability and vagueness in the response. In general, in such unverifiable circumstances, Fuzzy Multi-Criteria Decision Making (FMCDM) is used. The data have been collected on a scale of 1 and 5, where 5 represents highly satisfied, 4-satisfied, 3-undecided, 2-dissatisfied and 1 represents highly dissatisfied. Moreover, it has been observed while conducting a preliminary field study that males and females have different perception on the selected parameters. Apparently the females have given higher rating on the conduct of a physician. The reason may be that the expectations of females are less when compared to those of males. Moreover, rural women usually do not go out beyond the village boundary and thus do not have enough expousure to know about the conditions in other places. Therefore the data has been collected separately for males and females. Sample data collected is shown in Table 6.20**.** Weightages of the parameters have been found out on a scale between 1 and 5, where 1 represented not at all important and 5 as highly important. The opinion on the importance of the parameters, by males and females has been found to be same. The weights are shown in Table 6.21.

Table 6.20. Perception of females and males on CHC

S.No	Village name	CHC location	Waiting time		Availability of physician		Availability of Medicine		Conduct of the Physicians	
			M	F	M	F	M	F	M	F
1	Kolilarabad	Shahajanpur	5	5	3	3	3	3	4	3
2	Bantkhani	Shahajanpur	5	4	2	5	3	3	4	3
3	Kolilasanga	Neerman	4	5	3	2	3	3	3	2
4	Kolilajoga	Neerman	4	5	5	3	3	3	3	2
5	Mohladiya	Behror	4	5	3	5	3	3	2	2
6	Madhosingh	Behror	5	5	2	3	3	3	2	2
7	Janaksinghpura	Shahajanpur	2	5	3	2	3	3	2	2
8	Kali pahari	Behror	5	5	3	3	3	3	4	2
9	Huriakhund	Mandhan	5	4	5	3	3	3	4	3
10	Pholadppur	Shahajanpur	5	5	3	3	3	3	4	4
11	Ishansinghpura	Shahajanpur	5	5	2	2	3	3	4	2
12	Bawali	Shahajanpur	5	5	5	3	3	3	4	2
13	Sanseri	Shahajanpur	4	2	3	3	3	3	3	2

M- Males; F-Females

Table 6.21. Weights on criteria

S.No	Parameters	Weight scores
1	Waiting time	3
2	Availability of Physician	4
3	Availability of Medicine	4
4	Conduct of the physician	5

6.4.2.2.1 Fuzzy weighted aggregation method

The ratings on the parameters are subjective in nature and thus there would be uncertainty and ambiguity in assessing them. In such uncertain situations, Fuzzy Multi-

Criteria Decision Making (FMCDM) may be used effectively. The concept behind fuzzy interpretation provides a remarkably simple way to draw definite conclusions from vague, ambiguous or imprecise information. The decision making process in fuzzy logic resembles human decision making where precise solutions are found from approximate data. Fuzzy set theory has been applied in many studies using different types of fuzzy techniques, such as a fuzzy inference system, fuzzy aggregation method, fuzzy regression, and fuzzy clustering. Among these techniques, the fuzzy aggregation method is suitable for the quantification of villager's response as both ratings and weights are fuzzy in nature. Also, it is easy to execute and interpret.

6.4.2.2.2 Brief Introduction to Fuzzy Logic

The theory of fuzzy sets was first proposed by Zadeh in 1965. A fuzzy set is a class of elements or objects without any definite boundaries between them. The fuzzy logic is useful to define the real world objects which are characterized by vagueness and uncertainty. It is a multivalued theory wherein intermediate values such as “moderate”, “high”, “low” are used to define a condition instead of yes or no, true or false as in the case of conventional crisp theory. The fuzzy sets are defined by the membership functions. If a fuzzy number $\tilde{A}$ is a fuzzy set, and its membership function is $\mu_{\tilde{A}}(x)$: R → [0, 1] (Chen, 1997; Chan et al., 1999), where *‘x’* represents the criteria. Generally, linear membership function is used and the corresponding fuzzy numbers are called Triangular Fuzzy Numbers (TFNs), whose membership is defined by three real numbers *(l, m, n),* which is pictorially shown in Fig. 6.14.

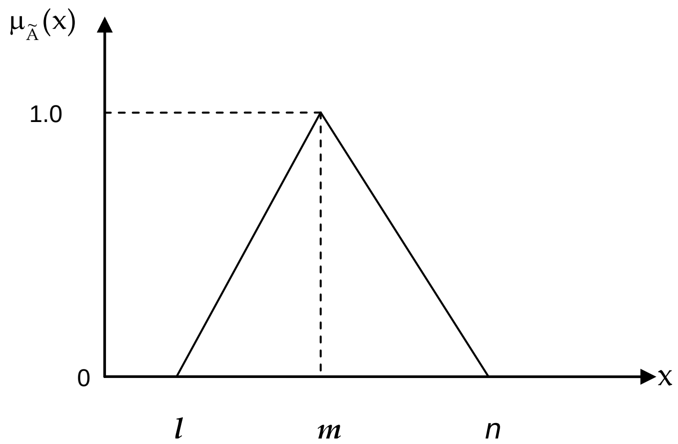


Fig 6.14: Membership Function for the Triangular Fuzzy Numbers

In Fig. 6.1, *m* is the most possible value of a fuzzy number $\tilde{A}$, and *l* and n are the lower and upper bounds respectively.The TFNs can be expressed as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{(x-l)}{(m-l)}; & l \le x \le m; \\ \frac{(n-x)}{(n-m)}; & m \le x \le n; \\ 0; & \text{Otherwise;} \end{cases} \qquad (5.1)$$

Operations on fuzzy numbers

Let $\tilde{A} = (l, m, n)$ and $\tilde{B} = (p, q, r)$ two TFNs, the general operations are as follows (Prakash, 2003).

- Addition of two fuzzy numbers
  $(l, m, n) \oplus (p, q, r) = (l + p, m + q, n + r)$
- Subtraction of two fuzzy numbers
  $(l, m, n) \Theta (p, q, r) = (l - r, m - q, n - p)$
- Multiplication of two fuzzy numbers
  $(p, q, r) \otimes (l, m, n) = (\max(pl, pm, rl, rn), qm, \min(pl, pm, rl, rn))$
- Division of two fuzzy numbers
  $(l, m, n) \div (p, q, r) = \left(\max\left(\frac{l}{p}, \frac{l}{r}, \frac{n}{p}, \frac{n}{r} \right), \frac{m}{q}, \min\left(\frac{l}{p}, \frac{l}{r}, \frac{n}{p}, \frac{n}{r} \right) \right)$

Where the symbols $\oplus, \Theta, \otimes$ represent fuzzy addition, fuzzy subtraction and fuzzy multiplication respectively.

6.4.2.2.3 Construction of Membership Functions

Two membership functions were constructed, including five scales of linguistic statement and the importance of the weight of five criteria. The triangular membership function was determined after an initial review of the data. To find the first membership functions for five scales of linguistic statements, the universe interval, from 0 to 1.0 has been considered in this study.

From the review of the sample data and their histogram plots it has been inferred that triangular fuzzy membership functions was the most suitable type of membership function for representing the weights and ratings. Moreover, triangular membership functions are simple to implement and fast for computation. A triangular membership function is specified by three parameters {a, b, c}, and the precise appearance of the function is determined by the choice of parameters. The membership function of fuzzy sets that represents letter grades for weights and ratings are shown in Table 6.23, 6.24 and are represented graphically in Fig 6.15 and 6.16 respectively.

Table 6.23. Membership Function of Fuzzy Sets that represents letter Grades for Weights

Triangular function			
Descriptors for Weights	**a**	**b**	**c**
Extremely Important	0.7	1	1
Very Important	0.5	0.7	0.9
Important	0.3	0.5	0.7
Important to some extent	0.1	0.3	0.5
Not at all Important	0	0.1	0.3

Table 6.24. Membership Function of Fuzzy Sets that represents letter Grades for ratings

Triangular function			
Descriptors for ratings	**a**	**b**	**c**
Very good	0.75	1	1
Good	0.5	0.75	1
Fair	0.25	0.5	0.75
Satisfactory	0	0.25	0.5
Poor	0	0	0.25

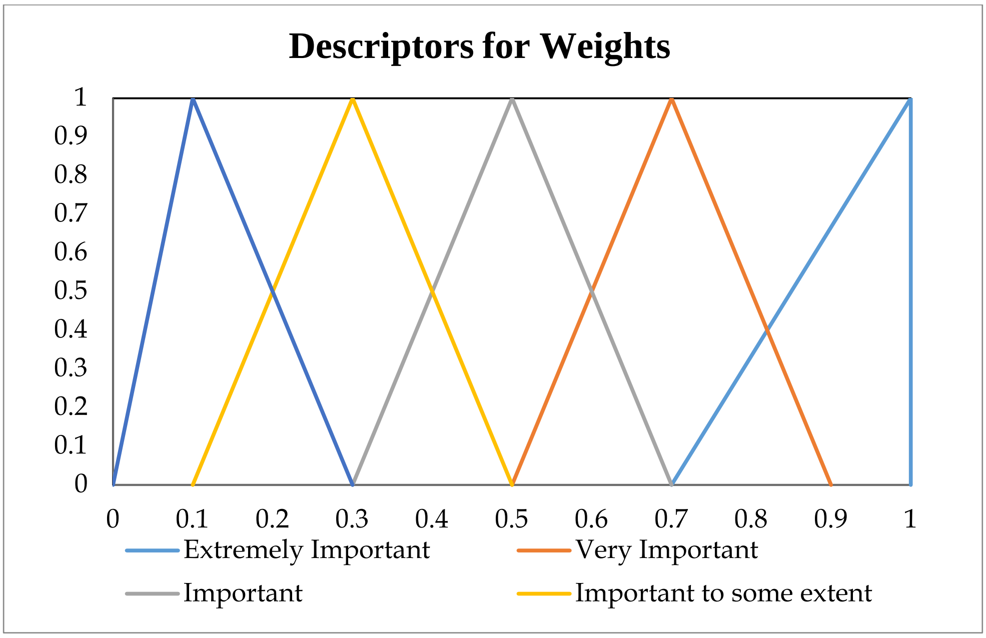


Fig. 6.15. Descriptors for Weights

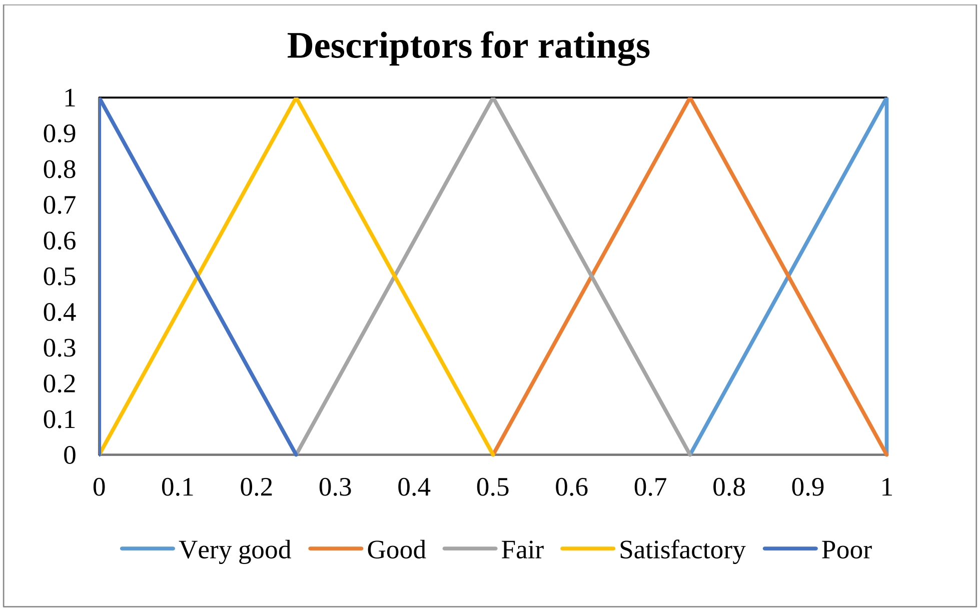


Fig. 6.16. Descriptors for Ratings

6.4.2.2.4 Fuzzification of crisp values

Fuzzification is the process of making a crisp quantity fuzzy. These linguistic variables were first converted into weights and ratings and then were expressed in Triangular Fuzzy Number (TFNs). For example the fuzzified number of the weights are shown in Table 6.25. The crisp values shown in the third row of table 6.25 are fuzzified using the membership function defined in table 6.23. Similarly, all the ratings have also been converted to a fuzzy triangular number using Table 6.24. Sample data of Alwar district have been shown in table 6.26.

Table 6.25. Fuzzification of weights

S.No	Parameters	Weight	Triangular Fuzzy number
1	Waiting time	3	(0.3,0.5,0.7)
2	Availability of physician	4	(0.5,0.7,0.9)
3	Availability of Medicine	4	(0.5,0.7,0.9)
4	Conduct of the physician	5	(0.7,1,1)

Table 6.26. Fuzzification of ratings

S.No	Waiting time	Availability of physician	Availability of Medicine	Conduct of the physician
1	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
2	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
3	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
4	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
5	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
6	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
7	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
8	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
9	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
10	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
11	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
12	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)
13	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
14	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
15	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
16	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
17	(0.75,1,1)	(0.25,0.5,0.75)	(0.75,1,1)	(0,0.25,0.5)
18	(0.75,1,1)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)

6.4.2.2.5 Evaluation and aggregation of Perception of Service Quality

The fuzzified ratings and weights on each criteria, are used to calculate a fuzzy weighted average. The triangular fuzzy number of weights is multiplied to the triangular fuzzy number of rating using fuzzy multiplication formula and then aggregated. Sample of aggregated data is shown in Table 6.27.

Table 6.27. Fuzzy multiplication and normalization

S.No	$\sum_{k=1}^{N} \tilde{W}_k \otimes \tilde{R}_k$	$\frac{\sum_{k=1}^{N} \tilde{W}_k \otimes \tilde{R}_k}{\sum_{k=1}^{N} \tilde{W}_k}$
1	(0.825,1.95,3.05)	(0.2,0.57,1.33)
2	(0.825,1.95,3.05)	(0.2,0.57,1.33)
3	(0.825,1.95,3.05)	(0.2,0.57,1.33)
4	(0.475,1.45,2.55)	(0.11,0.43,1.11)
5	(0.475,1.45,2.55)	(0.11,0.43,1.11)
6	(0.475,1.45,2.55)	(0.11,0.43,1.11)
7	(0.25,1.075,2.2)	(0.06,0.32,0.96)
8	(0.825,1.95,3.05)	(0.2,0.57,1.33)
9	(0.825,1.95,3.05)	(0.2,0.57,1.33)
10	(0.825,1.95,3.05)	(0.2,0.57,1.33)
11	(0.825,1.95,3.05)	(0.2,0.57,1.33)
12	(0.825,1.95,3.05)	(0.2,0.57,1.33)
13	(0.4,1.325,2.55)	(0.1,0.39,1.11)
14	(0.475,1.45,2.55)	(0.11,0.43,1.11)
15	(0.475,1.45,2.55)	(0.11,0.43,1.11)
16	(0.65,1.7,2.8)	(0.15,0.5,1.22)
17	(0.25,1.075,2.2)	(0.06,0.32,0.96)
18	(0.725,1.8,2.775)	(0.17,0.53,1.21)

6.4.2.2.6 Defuzzification

Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value. In simple words, it is the process of converting the fuzzy output back to crisp values. Generally used techniques are maximum defuzzification technique, centroid defuzzification technique, weighted average defuzzification technique, fuzzy clustering defuzzification, adaptive integration. However, centroid method is the most commonly used technique and is very accurate (Sugeno and Yasukawa 1993; Lee, 1990). This method is also known as the center of gravity or center of area defuzzification. This technique was developed by Sugeno. In this study centroid method is used for defuzzifying the triangular fuzzy number. It returns the center of the area under the curve. The centroid defuzzification formula is expressed in Eq 6.7.

$$x^{*} = \frac{\int \mu_i(x)xdx}{\int \mu_i(x)dx} \qquad (6.7)$$

where x^* is the defuzzified output, $\mu_i(x)$ is the aggregated membership function and x is the output variable. The sample defuzzified values are shown in table 6.28.

Table 6.28. Defuzzified crisp values

S.No	Final TFN	Crisp value
1	(0.2,0.57,1.33)	0.5
2	(0.2,0.57,1.33)	0.5
3	(0.2,0.57,1.33)	0.5
4	(0.11,0.43,1.11)	0.44
5	(0.11,0.43,1.11)	0.44
6	(0.11,0.43,1.11)	0.44
7	(0.06,0.32,0.96)	0.38
8	(0.2,0.57,1.33)	0.5
9	(0.2,0.57,1.33)	0.5
10	(0.2,0.57,1.33)	0.5
11	(0.2,0.57,1.33)	0.5
12	(0.2,0.57,1.33)	0.5
13	(0.1,0.39,1.11)	0.44
14	(0.11,0.43,1.11)	0.44
15	(0.11,0.43,1.11)	0.44
16	(0.15,0.5,1.22)	0.47
17	(0.06,0.32,0.96)	0.38
18	(0.17,0.53,1.21)	0.46

Similarly, in the same procedure crisp value rating was calculated for the females and the results between both the genders have been compared using statistical tests. A t-test was conducted in SPSS and the p-value obtained is 0.0012. Hence it is concluded that there is a significant difference between the opinions of both males and females at 95% confidence interval. Therefore, separate accessibility has been calculated for females and males. The last column in table 6.29 shows the CHC location on which villagers of Alwar district have given their opinion.

Table 6.29. Crisp values for males and females

S.No	Crisp value for males	Crisp value for females	CHC Location
1	0.5	0.56	Behror
2	0.5	0.46	Behror
3	0.5	0.5	Behror
4	0.44	0.5	Neemrana
5	0.44	0.38	Neemrana
6	0.44	0.5	Neemrana
7	0.38	0.5	Neemrana
8	0.5	0.5	Shahajanpur
9	0.5	0.57	Shahajanpur
10	0.5	0.55	Shahajanpur
11	0.5	0.53	Shahajanpur
12	0.5	0.45	Shahajanpur
13	0.44	0.5	Mandhan
14	0.44	0.5	Mandhan
15	0.44	0.5	Mandhan
16	0.47	0.53	Majari Kalan
17	0.38	0.5	Majari Kalan
18	0.46	0.5	Majari Kalan

The crisp opinions corresponding to a CHC by different habitations have been averaged. The final averaged perception values of the villagers and HSR values for all the CHC in five districts are presented in table 6.30. Weightages to HSR and V have been given in consultation with health experts which included physicians and block health officials. Slightly more weightage has been given to people's perception on CHC as they are the ultimate end users. The weightage of 0.6 has been given to V and 0.4 has been given to HSR. By using these weightages and the values obtained on HSR and V, the total quality of service provided by each CHC has been calculated separately for both the genders. From the results presented in table 6.30, it may be observed that the females have a slightly better opinion on the CHC quality in most of the cases. As per females, the highest quality of service is provided by Majrikalan CHC with a value of 0.63. Majarikalan CHC has better facilities and service when compared to other CHC and thus has been reflected in HSR and also villagers opinion rating. Males also have given high rating on the same CHC. However, the highest was obtained by Singhana (0.60). Though no much variation has been observed between the values of CHCs, they are ranging in between 0.45 to 0.6 in males and 0.44 to 0.63 for females.

Table 6.30. Quality of service of CHCs

S.No	CHC location	Block	District	Males			Females		
				HSR	V	Q	HSR	V	Q
1	Behror	Behror	Alwar	0.50	0.45	0.47	0.50	0.55	0.53
2	Shahajanpur	Neemrana	Alwar	0.55	0.46	0.50	0.55	0.51	0.52
3	Neemrana	Neemrana	Alwar	0.44	0.49	0.47	0.44	0.58	0.53
4	Mandhan	Neemrana	Alwar	0.49	0.48	0.48	0.49	0.57	0.54
5	Majarikalan	Neemrana	Alwar	0.64	0.52	0.57	0.64	0.62	0.63
6	Newai	Newai	Tonk	0.71	0.45	0.55	0.71	0.39	0.45
7	Buhana	Buhana	Jhunjhunu	0.53	0.49	0.50	0.53	0.50	0.51
8	Singhana	Buhana	Jhunjhunu	0.69	0.54	0.60	0.69	0.47	0.56
9	Ratangarh	Ratangarh	Churu	0.57	0.42	0.48	0.57	0.39	0.46
10	Lunkransar	Lunkransar	Bikaner	0.67	0.39	0.51	0.67	0.40	0.51
11	Mahajan	Lunkransar	Bikaner	0.47	0.44	0.45	0.47	0.42	0.44

6.4.3 Quantification of Mobility

Mobility is defined as the ease of movement of individuals between two places. The individual's choice of mode varies according to their socio-economic backgrounds and ownership of modes of transport. The two important quantifiable indicators of mobility are travel time and travel cost, which indirectly reflect the mode of transport used. Quality data of the road used by the individuals to reach CHC has also been collected as it influences the travel time. But very less variation has been observed in the data set therefore the quality parameter was not considered in this study. In this study, travel time and travel cost are the two parameters considered to measure mobility.

From the survey data it was observed that the villagers use different kinds of modes to travel to CHCs. Mode-wise mobility of the villagers is also found using fuzzy aggregation methods. Mobility is found mode-wise by finding out the travel time and travel cost taken by each mode to reach the health center. Again the weightages on the importance of the parameters considered for the study were found through questionnaire survey. The most frequently used modes to reach CHC by the individuals with different socioeconomic background are considered in the study. They are walking, bus, taxi and bicycle. It was noted that the significant data sample of travel time and travel cost for all the four modes was obtained only in Alwar district. In the other districts, number of people using buses and taxis were high as the habitations are located far from the CHCs. Number coding has been utilized for modes for simple comprehension (table 6.31).

In this study only in-vehicle travel time was considered for mode 2 and mode 3 i.e., bus and taxi respectively. Waiting time for the public transport, i.e., bus (Mode 2) and private hired vehicles (taxis; Mode 3) was not considered. From the interaction with the villagers it was noted that most of the public buses maintain a pre-scheduled timetable and the villagers need not wait for a long time to avail the service. For the emergency cases, taxis such as tempo, jeep, car and van are hired depending on the availability. These vehicles are usually readily available in the village at any time of the day.

Table 6.31.Numerical code for mode

S.No	**Mode**	**Code**
1	Walking	1
2	Bus	2
3	Taxi	3
4	Bicycle	4

The sample data collected through surveys in Alwar district is shown in Table 6.32. The travel time and cost data representation is for the total trip i.e., to and fro. As the data was collected only in a few selected habitations, relationship have been developed between travel distance and travel time and travel distance and travel cost. Using the models, the travel time and cost in all other habitations were predicted. For a constant travel distance, travel time and travel cost vary for the type of mode. Henceforth accessibility is a function of mode of travel.

Table 6.32 Travel characteristics of villagers

S.No	**Village name**	**Location of CHC visited**	**Distance from CHC**	**Travel time(min)**	**Travel cost(Rs.)**	**Usual mode of travel**
1	Kolilarabad	Shahajanpur	12.86	10	100	3
2	Bantkhani	Shahajanpur	9.94	20	12	2
3	Kolilasanga	Neerman	8.45	30	80	3
4	Kolilajoga	Neerman	8.41	30	80	3
5	Mohladiya	Behror	7.3	30	50	3
6	Madhosingh	Behror	5.79	12	10	2
7	Janaksinghpura	Shahajanpur	2.24	15	0	1
8	Kali pahari	Behror	0	10	0	1
9	Umaogarh	Behror	2.1	10	0	1
10	Huriakhund	Mandhan	3.16	10	25	3
11	Pholadppur	Shahajanpur	5.36	20	40	3
12	Ishansinghpura	Shahajanpur	7.5	25	0	4

S.No	Village name	Location of CHC visited	Distance from CHC	Travel time(min)	Travel cost(Rs.)	Usual mode of travel
13	Bawali	Shahajanpur	3.83	10	5	2
14	Sanseri	Shahajanpur	4.03	30	40	3
15	Jonayachakhurd	Shahajanpur	3.91	13	25	3
16	Banijonayacha	Shahajanpur	11.39	20	100	3
17	Shahyhampur	Shahajanpur	13.54	30	0	4
18	Chobara	Shahajanpur	11.13	25	15	2
19	Gugalkota	Shahajanpur	6.57	14	10	2
20	Nanagwar	Mandhan	19.77	60	30	2
21	Chawandi	Mandhan	18.5	40	150	3

6.4.3.1 Development of relation between travel distance and travel time and relation between travel distance and travel cost

A linear regression model has been developed by considering travel time (in min) as the dependent variable and travel distance (in km) as the independent variable. Regression models have also been developed by considering the travel cost (in Rs) as the dependent variable and travel distance (in km) as the independent variables. The relation between travel cost and the distance could not be developed for mode 1 and 4 as there is no travel cost for these modes. The plot between travel distance and travel time for modes 1 to 4 in Alwar district are shown in Fig 6.17, 6.18, 6.19 and 6.20 respectively. All the regression models developed and their corresponding R^2 values are presented in table 6.33. Additionally to check the robustness of the models, the Analysis of Variance (ANOVA) and Standard Error of Estimate (SEE) were calculated and were found to be significant and within the acceptable limits for all the models.

From the individual travel behaviour, it has been observed that people walk (mode 1) if the distance is less than 2.5 km. If the individuals travel for more than 2.5 km to reach health care they use car, taxi or public transport and sometime bicycle. The usage of public transport (mode 2) and taxi (mode 3) is observed only if the distance is more than 2.5 km and this is the reason behind the negative constant of the equations for mode 2 and 3.

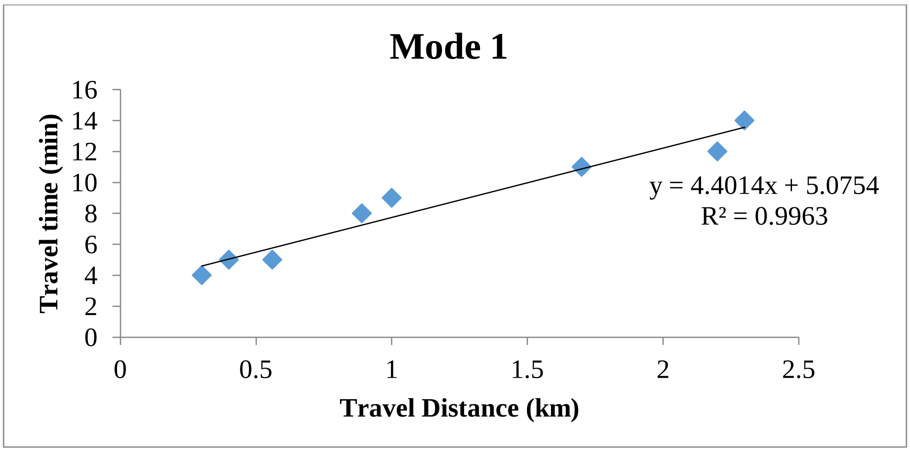


Fig. 6.17. Plot between Travel distance and Travel time (Mode 1)

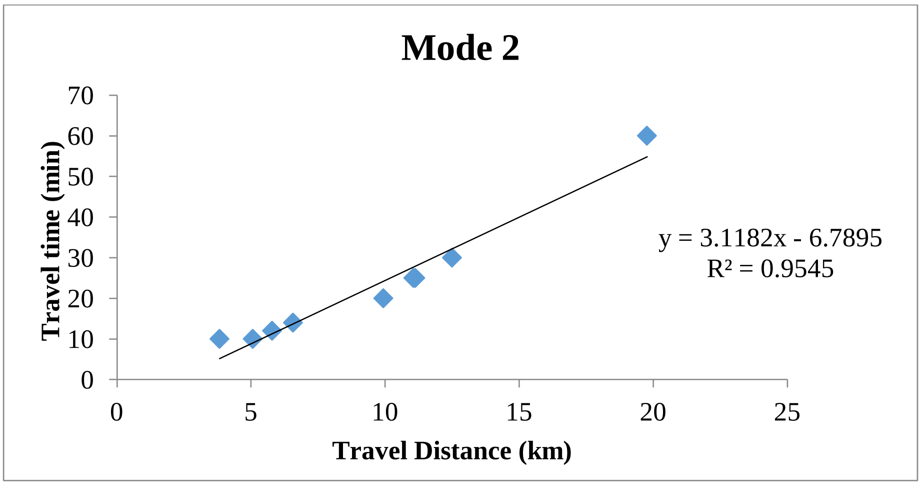


Fig. 6.18. Plot between Travel distance and Travel time (Mode 2)

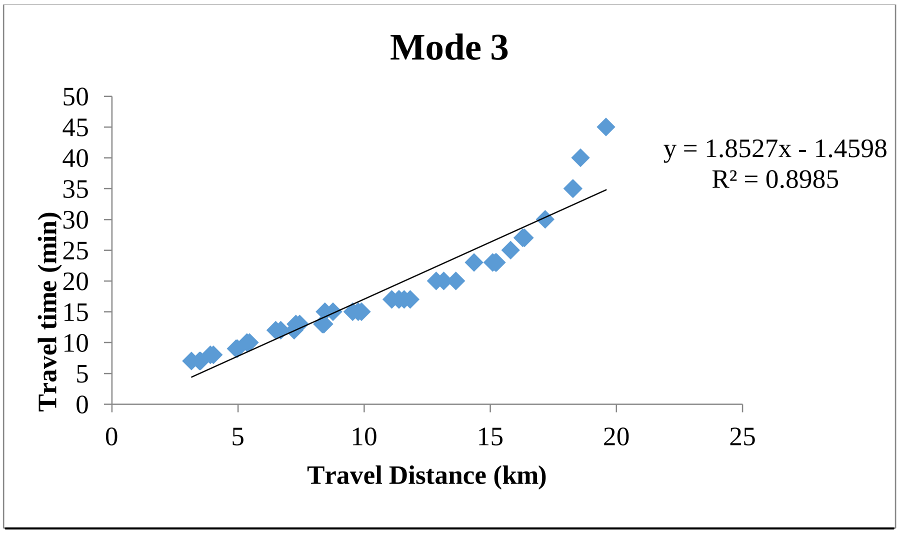


Fig. 6.19. Plot between Travel distance and Travel time (Mode 3)

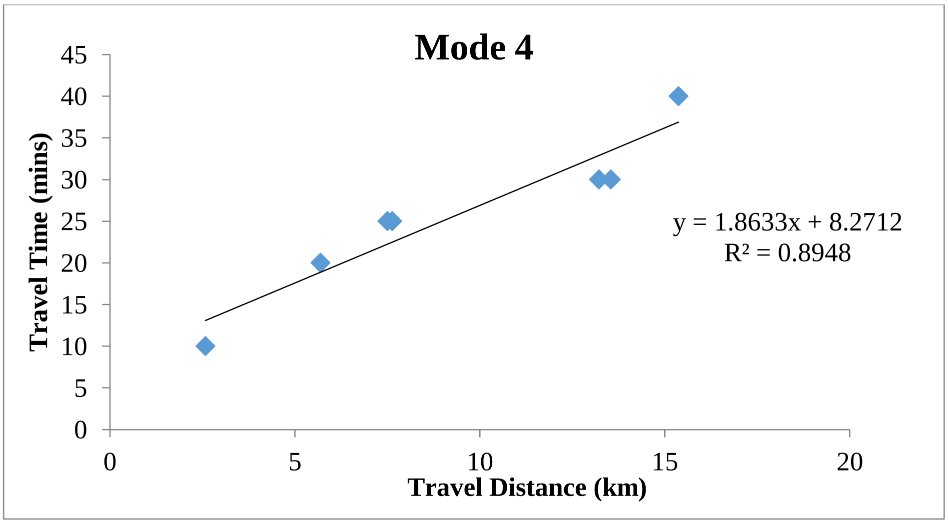


Fig. 6.20. Plot between Travel distance and Travel time (Mode 4)

Table 6.33. Regression models developed for modes

District	Mode	Travel time	Travel cost
Alwar	1	$y = 4.4014x + 5.0754$ **(R^2 = 0.9963)**	-
	2	$y = 3.1182x - 6.7895$ **(R^2 = 0.9545)**	$y = 1.5278x - 1.2075$ **(R^2 = 0.966)**
	3	$y = 1.8527x - 1.4598$ **(R^2 = 0.8985)**	$y = 14.277x - 39.466$ **(R^2 = 0.947)**
	4	$y = 1.8633x + 8.2712$ **(R^2 = 0.8948)**	-
Tonk	2	$y = 3.4013x - 20.502$ **(R^2 = 0.8036)**	$y = 1.0627x + 3.472$ **(R^2 = 0.793)**
	3	$y = 3.3449x - 26.666$ **(R^2 = 0.774)**	$y = 6.3897x - 18.776$ **(R^2 = 0.766)**
Jhunjhunu	2	$y = 2.0462x + 6.61$ **(R^2 = 0.889)**	$y = 0.9679x + 3.9905$ **(R^2 = 0.823)**
	3	$y = 2.0861x + 2.315$ **(R^2 = 0.822)**	$y = 6.2346x + 22.039$ **(R^2 = 0.859)**
Churu	2	$y = 1.9787x - 0.1502$ **(R^2 = 0.777)**	$y = 1.2421x + 0.221$ **(R^2 = 0.814)**
	3	$y = 1.4153x + 4.5087$ **(R^2 = 0.802)**	$y = 6.1807x - 4.1851$ **(R^2 = 0.754)**
Bikaner	2	$y = 3.1882x - 23.057$ **(R^2 = 0.880)**	$y = 1.3541x - 7.0558$ **(R^2 = 0.828)**
	3	$y = 1.2413x + 6.5026$ **(R^2 = 0.941)**	$y = 8.3701x - 63.991$ **(R^2 = 0.943)**

6.4.3.2 Model validation

To ascertain the statistical significance of the models developed for travel time and travel cost, randomly 70% of the observed values was used for developing the regression models and the remaining 30% was kept aside for the model validation. The deviation between observed travel time and the predicted travel time was calculated for each mode. The deviation between observed travel cost and the predicted travel cost was also calculated for each mode. The calculation of Mean Absolute Percentage Deviation (MAPD) for Alwar district for all the modes are presented in Table 6.34. Similarly MAPD has been calculated for remaining four districts for only two modes, mode 2 and mode 3. The MAPD of all the districts were ranging from 3.2 to 6.98%. Only in a few cases, the variation between observed and predicted values was more than 5%. It may be due to the fact that, all the possible parameters were not considered while developing the model and some of the parameters such as poor quality of the road and waiting time had substantial impact in a few stretches.

Table 6.34. Calculation of MAPD of Mobility for Alwar district

		Mode 1			**Mode 2**						**Mode 3**						**Mode 4**		
		Travel time			**Travel time**			**Travel cost**			**Travel time**			**Travel cost**			**Travel time**		
S.No	**Travel distance**	**O**	**P**	**% D**	**O**	**P**	**% D**	**O**	**P**	**% D**	**O**	**P**	**% D**	**O**	**P**	**% D**	**O**	**P**	**% D**
1	5.41	25	29	16	10	10	0.8	8	7.1	12	10	8.6	14	40	38	5.7	20	18	8.3
2	6.37	30	33	10	15	13	13	8	8.5	6.5	10	10	3.4	50	51	2.9	20	20	0.7
3	6.99	35	36	2.4	15	15	0.1	10	9.5	5.3	12	11	4.3	60	60	0.5	20	21	6.5
4	7.99	40	40	0.6	20	18	9.4	10	11	10	15	13	11	75	75	0.6	25	23	7.4
5	9.31	45	46	2.3	20	22	11	15	13	13	15	16	5.3	90	93	3.8	25	26	2.5
6	9.39	45	46	3.1	20	22	12	12	13	9.5	15	16	6.3	95	95	0.5	25	26	3.1
7	10.62	50	52	3.6	25	26	5.3	15	15	0.1	20	18	8.9	110	112	1.9	30	28	6.5
8	10.71	54	52	3.3	25	27	6.4	15	15	1.1	20	18	8.1	100	113	13	30	28	5.9
9	11.97	60	58	3.7	30	31	1.8	18	17	5.1	20	21	3.6	130	131	1	30	31	1.9
10	12.34	60	59	1	30	32	5.6	18	18	1.9	20	21	7	130	137	5.1	30	31	4.2
11	13.34	65	64	1.9	35	35	0.5	20	19	4.2	25	23	7	150	151	0.6	35	33	5.3
12	13.47	65	64	1	35	35	0.6	20	19	3.2	25	24	6	150	153	1.8	35	33	4.7
13	14.03	65	67	2.8	35	37	5.6	20	20	1.2	25	25	1.9	160	161	0.5	35	34	1.7
14	14.87	75	75	0.1	40	43	6.8	25	23	7.8	30	28	6.9	180	187	3.9	40	38	5.4
15	14.9	90	88	1.9	50	52	4.3	26	28	6.4	35	34	4.1	250	230	7.9	45	43	3.4
Mean Absolute Percentage Deviation				3.6			5.6			5.8			6.5			3.3			4.5

O-Observed values; P-Predicted values; %D- Absolute % Deviation

Prior to finding out the mobility of habitations using different modes, the travel times and travel costs were predicted based on their distance from the CHC. The travel times and costs are absolute values, and they were converted into 1 to 5 scale. The class interval for all the predicted travel times and travel cost data was calculated by subtracting the maximum and minimum values in a group. Then the class interval was divided by 5, to obtain the ranges for each class. Then all the travel times and travel cost values were represented between 1 and 5 depending on the absolute values. The conversion to 1 to 5 scale is necessary as the response obtained on the importance of travel time and travel cost were on a five point scale: 5- Very important, 4 – Important, 3-Undecided, 2- Not important, 1-Not very important.

For example, the sample data of absolute travel time for mode 1 to 4 in Alwar district are shown in the table 6.35, maximum and minimum travel time taken to reach CHC using any mode are identified. The class interval range is computed by subtracting minimum and maximum value in the group divided by the number of class groups (i.e., 5). By using the class interval range, five groups have been classified using table 6.36. Using the range the data has been converted to scales between 1 and 5 and are presented in table 6.37. In the similar procedure for all the districts the scales were developed for time and cost as shown in table 6.38.

Table 6.35. Calculation of class interval range of Travel time

S.No	Distance	Travel Time			
		Mode 1	Mode 2	Mode 3	Mode 4
1	19.44	91.63	53.83	34.56	44.49
2	19.60	92.96	54.33	34.85	44.79
3	19.18	89.49	53.02	34.07	44.01
4	17.71	83.02	48.43	31.35	41.27
5	18.99	88.65	52.43	33.72	43.66
6	13.01	62.33	33.78	22.64	32.51
7	18.63	87.07	51.30	33.06	42.98
8	14.48	68.80	38.36	25.37	35.25
9	15.10	71.53	40.30	26.52	36.41
10	17.68	82.89	48.34	31.30	41.21
11	10.57	51.59	26.17	18.12	27.97
12	15.57	73.60	41.76	27.39	37.28
13	12.13	58.46	31.03	21.01	30.87
14	14.59	69.29	38.71	25.57	35.46
15	12.82	61.50	33.19	22.29	32.16
16	15.65	73.95	42.01	27.53	37.43
17	19.38	90.37	53.64	34.45	44.38
18	10.96	53.31	27.39	18.85	28.69
Max value					93

Min value	0
Class Interval range	19

Table 6.36. Scores developed for Travel time (Alwar district)

Travel Time	Score
0-19	5
19-38	4
38-57	3
57-76	2
76-95	1

Table 6.37. Travel time scores

	Travel Time scores			
S.No	**Mode 1**	**Mode 2**	**Mode 3**	**Mode 4**
1	1	3	4	3
2	1	3	4	3
3	1	3	4	3
4	1	3	4	3
5	1	3	4	3
6	2	4	4	4
7	1	3	4	3
8	2	3	4	4
9	2	3	4	4
10	1	3	4	3
11	3	4	5	4
12	2	3	4	4
13	2	4	4	4
14	2	3	4	4
15	2	4	4	4
16	2	3	4	4
17	1	3	4	3
18	3	4	5	4
19	5	5	5	5

Table 6.38. Scores developed for Travel time and Travel cost

District	Travel Time	Travel cost	Score
Alwar	0-19	0-50	5
	19-38	50-100	4
	38-57	100-150	3
	57-76	150-200	2
	76-95	200-250	1
Tonk	0-13	0-29	5
	13-26	29-58	4
	26-39	58-87	3
	39-52	87-116	2

	52-65	116-145	1

District	Travel Time	Travel cost	Score
Jhunjhunu	0-11	0-33	5
	11-22	33-66	4
	22-33	66-99	3
	33-44	99-132	2
	44-55	132-165	1
Churu	0-11	0-31	5
	11-22	31-62	4
	22-33	62-93	3
	33-44	93-124	2
	44-55	124-155	1
Bikaner	0-18	0-46	5
	18-36	46-92	4
	36-54	92-138	3
	54-72	138-184	2
	72-90	184-230	1

After converting all the travel times and costs into five point scale, fuzzy aggregation method was applied to get final mobility values for each mode. In order to determine the weights on travel time and cost, the data was collected at village-level during the questionnaire survey. The weights given by villagers are presented in Table 6.39. The aggregated weightages for travel time and cost are 3 and 4 respectively on a scale of 1 to 5. Similar steps as in calculation of perception of villagers are followed in calculating mobility. Same membership functions were used for weights and scores or ratings. Crisp weights and ratings are converted using table 6.23 and 6.24 respectively. The fuzzified values of weights and scores are shown in table 6.39 and table 6.40 respectively. Then the fuzzified weights and ratings are multiplied and aggregated. Centroid defuzzification technique has been used to defuzzify into crisp value and the calculated final crisp values are shown in Table 6.41. The sample final mobility values for all the modes are shown in Table 6.42.

Table 6.39. Weights on Travel time and Travel cost

S.No	Parameters	Weights	Triangular Fuzzy number
1	Travel time	3	(0.3,0.5,0.7)
2	Travel cost	4	(0.5,0.7,0.9)

Table 6.40. Fuzzification of crisp rating into Triangular fuzzy number

S.No	Mode 2				Mode 3			
	Travel time		Travel cost		Travel time		Travel cost	
1	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
2	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
3	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
4	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
5	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
6	2	(0,0.25,0.5)	4	(0.5,0.75,1)	4	(0.5,0.75,1)	4	(0.5,0.75,1)
7	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
8	2	(0,0.25,0.5)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	4	(0.5,0.75,1)
9	2	(0,0.25,0.5)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	4	(0.5,0.75,1)
10	1	(0,0,0.25)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	3	(0.25,0.5,0.75)
11	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	5	(0.75,1,1)	4	(0.5,0.75,1)
12	2	(0,0.25,0.5)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	4	(0.5,0.75,1)
13	2	(0,0.25,0.5)	4	(0.5,0.75,1)	4	(0.5,0.75,1)	4	(0.5,0.75,1)
14	2	(0,0.25,0.5)	3	(0.25,0.5,0.75)	4	(0.5,0.75,1)	4	(0.5,0.75,1)

Table 6.41. Defuzzified crisp values of mobility

S.No	$M_i^m = \frac{\sum_{l=1}^{N} \tilde{W}_l \otimes \tilde{R}_l}{\sum_{l=1}^{N} \tilde{W}_l}$	Defuzzified value
1	(0.05,0.21,0.94)	0.35
2	(0.05,0.21,0.94)	0.35
3	(0.05,0.21,0.94)	0.35
4	(0.05,0.21,0.94)	0.35
5	(0.05,0.21,0.94)	0.35
6	(0.17,0.6,1.72)	0.66
7	(0.05,0.21,0.94)	0.35
8	(0.05,0.35,1.22)	0.49
9	(0.05,0.35,1.22)	0.49
10	(0.05,0.21,0.94)	0.35
11	(0.17,0.6,1.72)	0.66
12	(0.05,0.35,1.22)	0.49
13	(0.17,0.6,1.72)	0.66
14	(0.05,0.35,1.22)	0.49
15	(0.17,0.6,1.72)	0.66

Table 6.42. Sample mobility values for mode 1-4 (Alwar district)

S.No	Travel Distance	Mode1	Mode2	Mode3	Mode4
1	4.44	0.76	0.75	0.75	0.77
2	6.88	0.74	0.75	0.75	0.74
3	7.99	0.67	0.75	0.75	0.68
4	8.8	0.67	0.75	0.75	0.68
5	9.02	0.67	0.75	0.75	0.68
6	9.03	0.67	0.75	0.75	0.68
7	10.57	0.63	0.66	0.66	0.64
8	11.63	0.61	0.65	0.66	0.62
9	12.13	0.60	0.63	0.65	0.62
10	12.82	0.59	0.62	0.64	0.61
11	13.01	0.55	0.52	0.50	0.59
12	13.98	0.53	0.51	0.50	0.59
13	14.59	0.49	0.49	0.46	0.57
14	14.9	0.49	0.43	0.35	0.57

It has been observed during data analysis that the villagers have given more weightage to travel cost when compared to travel time. Thus mobility values calculated for the modes 1 and 4 (i.e., walking and cycling) which are inexpense, were found to be higher. When compared between mode 1 and mode 4, mode 4 has higher mobility value as the travel time taken is lesser when compared to mode 1 and the operating cost is very low. For further lower distances less than 6 to 5 km, the mobility value for all the four modes are almost same as the cost taken by mode 2 and mode 3 are less and the travel time is also lower when compared to the other two modes. While at higher distances the mobility by mode 2 is higher when compared to mode 3 as a result of higher travel cost. The variation of the mobility values in between the modes for lower distance of travel is seen to be less. In all the districts same pattern has been observed.

Quantification of accessibility using two step procedure

Finally, accessibility was quantified using the weights on travel friction, quality of service, impedance due to travel on unpaved road and mobility. In ArcGIS using closest facility tool, the population served by each CHC within 15 km threshold distance was determined. After getting the output from GIS, using the distance from the CHCs, mobility values have been calculated for all the habitations falling within the catchment area. In Alwar district mobility has been calculated for all the four modes. Whereas in all other districts mobility was calculated for only two modes, modes 2 and 3 as the other modes were not used frequently by the villagers.

The assumptions in the previous methods, i.e., all the CHCs deliver the same quality of service have overcome in this method by giving weights on the quality of CHC. In the first step while calculating health care to population ratio, weights calculated for the quality of service of respective CHCs are multiplied in the numerator of equation 6.7. Closer the value of weight on CHC towards 1 indicate higher the quality of service provided by that CHC. The quality of CHC and mobility data input format for MATLAB are presented in table 6.43 and 6.44 respectively. For both the genders the calculated health care to population ratio are shown in the Table 6.45.

In the second step, the accessibility of each habitation is measured mode wise. The mobility value, travel friction weight, R_j values from the step 1 and weight for travelling on unpaved road are used as inputs for calculating accessibility. Accessibility is computed for both the genders and for four different modes using equation 6.8. The sample of results are shown in Table 6.46. MATLAB programme has been written for executing the calculations. The code has been attached in the *Appendix 7*.

The accessibility values for females is slightly higher when compared to those obtained for males as the female's perception on the quality of service was higher.

Table 6.43. Quality data input for MATLAB

CHC_ID	Q
1	0.47
2	0.49
3	0.46
4	0.48
5	0.56

Table 6.44. Population and mobility data input for MATLAB

S.No	FacilityID	HabitaionID	Travel distance	Population	F	$f(d_{ij})$	Mobility
1	3	11	13.31	2297	1.00	0.35	0.47
2	3	30	14.09	1297	1.00	0.27	0.48
3	3	31	13.1	1418	0.89	0.36	0.48
4	3	32	12.07	2209	0.89	0.43	0.48
5	3	34	8.94	1591	1.00	0.57	0.59
6	3	35	10.43	1800	0.56	0.50	0.57
7	3	36	14	1018	0.08	0.28	0.48
8	3	37	13.8	803	0.73	0.30	0.48
9	3	45	8.92	1077	0.65	0.57	0.59
10	3	46	10.31	1257	0.65	0.51	0.48
11	3	47	8.55	143	1.00	0.58	0.59
12	3	48	9.82	1433	1.00	0.53	0.67
13	3	49	6.37	1054	0.81	0.67	0.67
14	3	50	1.61	1297	1.00	0.92	0.78
15	3	51	1.47	1853	1.00	0.93	0.78

Table 6.45. Health care to population ratio for males and females

CHC location	Males			Females		
	Q	$\sum_i P_i * f(d_{ji})$	R_j (in 10^6)	Q	$\sum_i P_i * f(d_{ji})$	R_j (in 10^6)
Neemrana	0.47	74619.6	6.30	0.53	74619.67	7.15
Shahajapura	0.49	49495.4	10.04	0.52	49495.47	10.60
Mandhan	0.46	63458.2	7.36	0.52	63458.25	8.28
Behor	0.48	42037.8	11.49	0.53	42037.87	12.80
Mundawan	0.56	57600.2	9.88	0.62	57600.23	10.89
Newai	0.55	66058.5	8.34	0.44	66058.56	6.77
Buhana	0.50	116289.2	4.34	0.51	116289.2	4.39
Singhana	0.60	111722.0	5.37	0.55	111722.1	4.99
Ratangarh	0.47	68266.7	7.03	0.46	68266.71	6.76
lunkransar	0.50	57301.2	8.83	0.50	57301.26	8.86
Mahajan	0.45	25116.1	17.99	0.44	25116.19	17.57

Table 6.46. Accessibility Index for Males and Females

Habiation_ID	Mode 1		Mode 2		Mode 3		Mode 4	
	Males	Female	Males	Female	Males	Female	Males	Female
49	0.13	0.18	0.1	0.11	0.12	0.13	0.18	0.21
134	0.13	0.17	0.09	0.1	0.11	0.13	0.17	0.2
135	0.14	0.19	0.1	0.11	0.12	0.14	0.19	0.22
136	0.19	0.27	0.14	0.16	0.17	0.19	0.27	0.3
137	0.14	0.2	0.1	0.12	0.13	0.14	0.2	0.23
138	1.04	1.34	1.06	1.19	1.1	1.24	1.34	1.5
139	0.54	0.67	0.44	0.5	0.51	0.58	0.67	0.76
140	0.45	0.57	0.38	0.43	0.43	0.49	0.57	0.65
141	0.2	0.27	0.14	0.16	0.17	0.2	0.27	0.31
142	2.33	2.69	2.2	2.48	2.29	2.58	2.69	3.03
143	1.82	2.29	1.79	2.01	1.9	2.13	2.29	2.56
144	1.72	2.19	1.76	1.95	1.83	2.03	2.19	2.43
145	3.12	3.6	2.94	3.25	3.04	3.37	3.6	3.99
146	3.63	4.17	3.53	3.9	3.63	4.03	4.17	4.63
147	3.21	3.7	3.04	3.36	3.13	3.46	3.7	4.1
148	1.56	1.96	1.54	1.72	1.63	1.82	1.96	2.2
149	3.24	3.68	3.53	4	3.57	4.04	3.68	4.17
150	2.8	3.18	3.03	3.43	3.08	3.49	3.18	3.6

6.4.4 Statistical validation

The observed accessibility values have also been found by asking habitants, their satisfaction on the present accessibility level to CHC and also the overall satisfaction with the service provided by the nearest CHC. The opinions are collected on 1 to 5 scale, where 5 represents highly satisfied, 4-Satisfied, 3-Undecided, 2-Dissatisfied and 1 representing Highly dissatisfied. Different weightages have been given to two of these parameters based on villager's opinion. The weightage given by the villagers were largly varying in relation with the distance of their travel. The habitations, which are within 5 km travel distance for higher population density districts and 7 km for lower population density districts (Bikaner and Tonk) have given an average weight of 0.6 (on a normalized 0 to 1 scale) to the service provided by the CHC and 0.4 to the other. The reason for this can be deduced by the fact that the people staying close to the CHC give higher importance to the quality of CHC. The habitations, which travel more than 5km and 7km respectively in high and low density areas, have given 0.8 weight to the overall accessibility to the health care and 0.2 weights to the other. These weights are multiplied with the rating of the respective parameters and aggregated. The final value is obtained on a scale 1 to 5.

The observed values of accessibility obtained on a scale of 1 to 5 are used to validate the results from M2SFCA method. The predicted or calculated accessibility values from the M2SFCA method are converted into 1 to 5 scale for a comparison with the observed accessibility values. The class interval of all the predicted accessibility values is calculated by subtracting the maximum extent value and the minimum extent value group of data. Then the class interval is divided by 5, to obtain class interval range and then the ungrouped data are grouped into 5 classes. To check the statistical validity, paired sample t-test has been conducted for 95% confidence interval. The t-test was conducted using Statistical Package for the Social Sciences (SPSS) software. The p-value obtained is 0.12, which is greater than 0.05, and thus indicates that there is no significant difference between two groups of data. M2SFCA method simulates the actual accessibility levels of the villagers.

The mean absolute percentage error (MAPE) has also been calculated to measure accuracy of the M2SFCA method in predicting accessibility values. The percentage error between observed and predicted accessibility value for Alwar district was 9.86%, which is quite acceptable considering the data collected from different habitations. The calculation of MAPE is presented in Table 6.47. In all the districts, the absolute percentage error was less than 10%. From the t-test and MAPE results it can be concluded that the predicted accessibility values from M2SFCA method significantly represent the actual accessibility of the villagers in all the districts.

Table 6.47. Calculation of MAPE for the accessibility values predicted using M2SFCA method

S.No	**Travel Distance**	**Overall accessibility to CHC**	**Overall satisfaction on service by CHC**	**Observed accessibility**	**Predicted accessibility**	**Absolute % of error**
1	14.15	1	2	1.2	1	16.67
2	13.56	1	2	1.2	1	16.67
3	13.55	2	2	2	2	0
4	13.32	2	2	2	2	0
5	12.01	1	3	1.4	2	42.86

6	11.67	2	2	2	2	0
7	11.59	2	2	2	2	0
8	11.45	1	2	1.2	2	66.67
S.No	**Travel Distance**	**Overall accessibility to CHC**	**Overall satisfaction on service by CHC**	**Observed accessibility**	**Predicted accessibility**	**Absolute % of error**
9	10.98	2	3	2.2	2	9.09
10	10.45	2	2	2	2	0
11	9.93	3	3	3	3	0
12	9.77	3	4	3.2	3	6.25
13	9.5	3	3	3	3	0
14	9.16	4	4	4	4	0
15	8.46	4	4	4	4	0
16	6.62	4	4	4	4	0
17	6.52	5	4	4.8	4	16.67
18	6.07	4	4	4	4	0
19	4.13	5	4	4.4	4	9.09
20	3.88	5	4	4.4	4	9.09
21	3.05	5	4	4.4	4	9.09
22	3.03	5	4	4.4	5	13.64
23	2.78	3	4	3.6	4	11.11
Mean absolute percentage error (**MAPE**)						9.865217

6.5. Summary

In this Chapter, accessibility at the habitational - level has been calculated using three different methods and methods were validated using statistical tests. The calibration of travel friction factor for varying population density has been discussed in detail. The quantification of quality of service using fuzzy logic has also been presented. The calculation of mobility by developing relationship between travel distance, travel time and travel cost is also discussed in detail in this chapter.

Chapter 7

Development of a Need-Based Approach for Rural Road Network Planning

7.1. Background

By utilizing the methodology proposed as a part of chapter 6, the present accessibility to all the sectors can be determined utilizing minor modifications. In addition to quantifying the present accessibility levels, it has been felt that a proper network level planning for road connectivity can boost the accessibility of the rural population to basic needs and can optimize the overall investments. Travel distance and travel time are the major factors having a profound impact on accessibility. In the rural road network developed using demand criterion, there is less possibility that all the villages will have accessibility to meet all the needs within a certain acceptable distance. A need-based network is expected to address this deficiency.

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 Sadak Yojana (PMGSY) to improve all-weather road connectivity in Indian villages. The provision of the connectivity to a village was decided based on population. But mere connectivity does not ensure accessibility to basic needs. In this study an endeavor is made to build up a need-based approach for rural connectivity which would ensure accessibility to the basic facilities using GIS platform. The analysis has been done with the map of the year 2000, just before the PMGSY programme launched.

Ideally, a village should have easy access to basic facilities when connected to an all-weather road. The primary objective of this study was developing a need-based road network. This study analyses the accessibility to basic facilities such as primary school (PS), middle school (MS), high school (HS), primary health centre (PHC) and local government (Panchayat) head quarter (PHQ).

The district of Tonk has been taken for detailed study so as to develop a need based rural road network. The preliminary data, including the map of Tonk district is shown in Fig 7.1. It shows the existing road network with all categories of roads and highways, namely State Highway (SH), Major District Roads (MDR), Other District Roads (ODR) and location of villages with block boundaries in different colors.

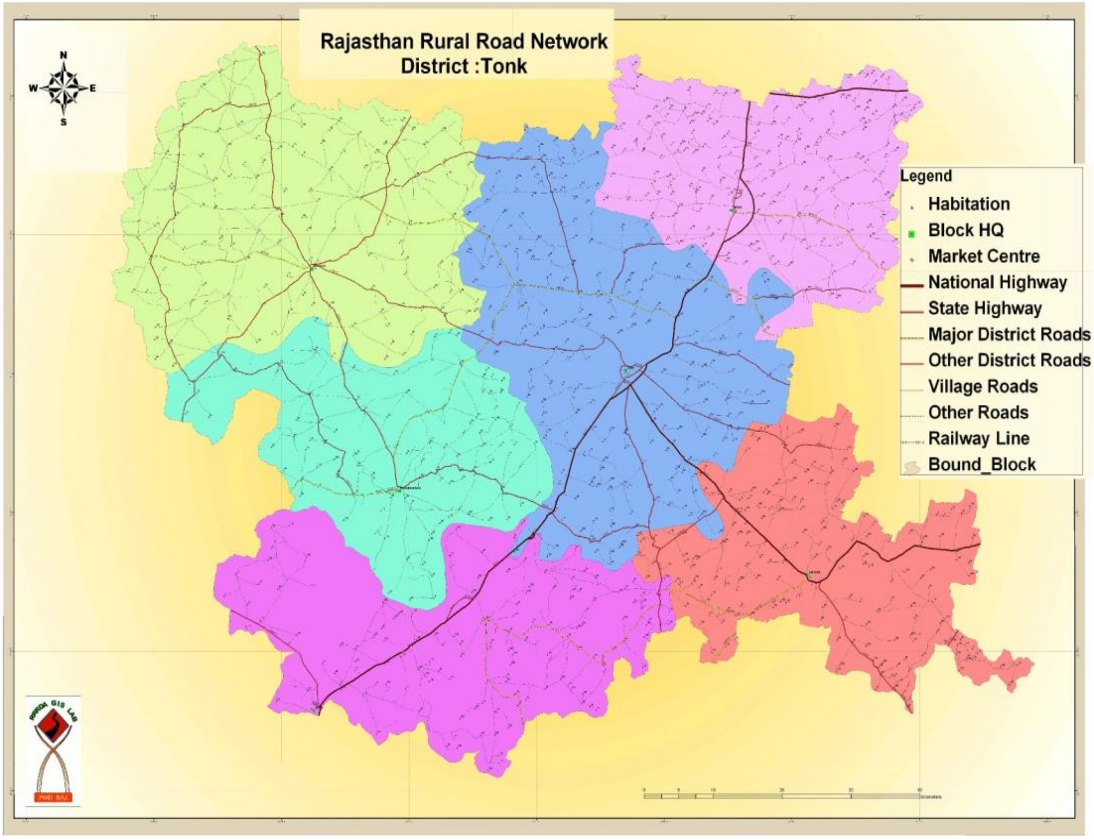


Fig 7.1. Map of Tonk District

The details of each village with population, facilities available such as school and health care facilities have also been collected. It has also mentioned, if the village is a Head Quarter of the block. A sample of data for a few selected villages is shown in Table 7.1. For the purpose of easy identification, each block and village are provided with separate IDs. The availability and unavailability of the facilities were indicated in terms of 1 and 0 respectively.

Table 7.1. Preliminary Data related facilities

S.No	BlockID	VillageID	Population	Head Quarters	Primary School	Middle School	High School	College	Primary Health Care
1	1	3	184	0	1	0	0	0	0
2	1	70	1285	1	0	1	1	0	0
3	1	125	417	0	1	0	0	0	0
4	1	113	5399	1	0	1	1	0	1
5	1	106	443	0	1	0	0	0	0
6	2	10	1628	1	1	0	1	0	0
7	2	3	1410	0	0	0	0	0	0
8	2	98	1503	1	1	0	1	0	0
9	2	134	702	0	1	0	0	0	0
10	2	49	774	0	0	1	0	0	0

In the first step of analysis **ArcGIS 10.0** has been used for geo-referencing and to digitize the location of villages and given road network, as shown in Fig 7.2. The present facilities in each village have also been highlighted in the map as shown as Fig 7.3. A blow-up of a selected area has been shown for better understanding in Fig 7.4.

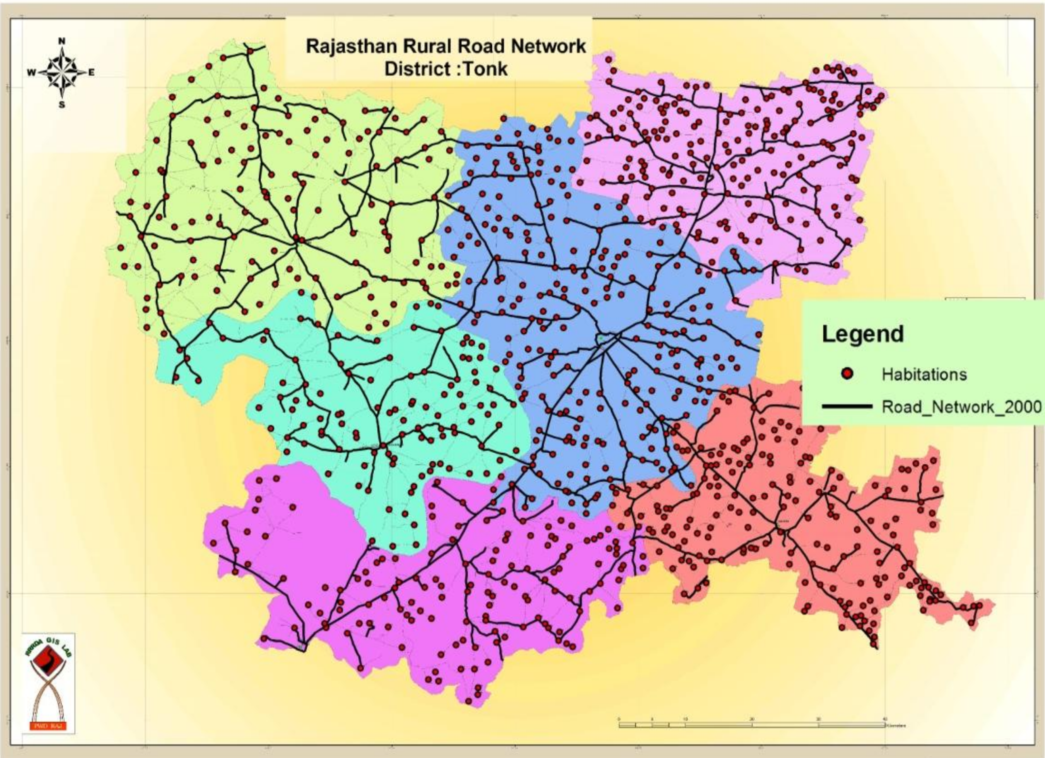


Fig 7.2. Digitized map with road network and villages

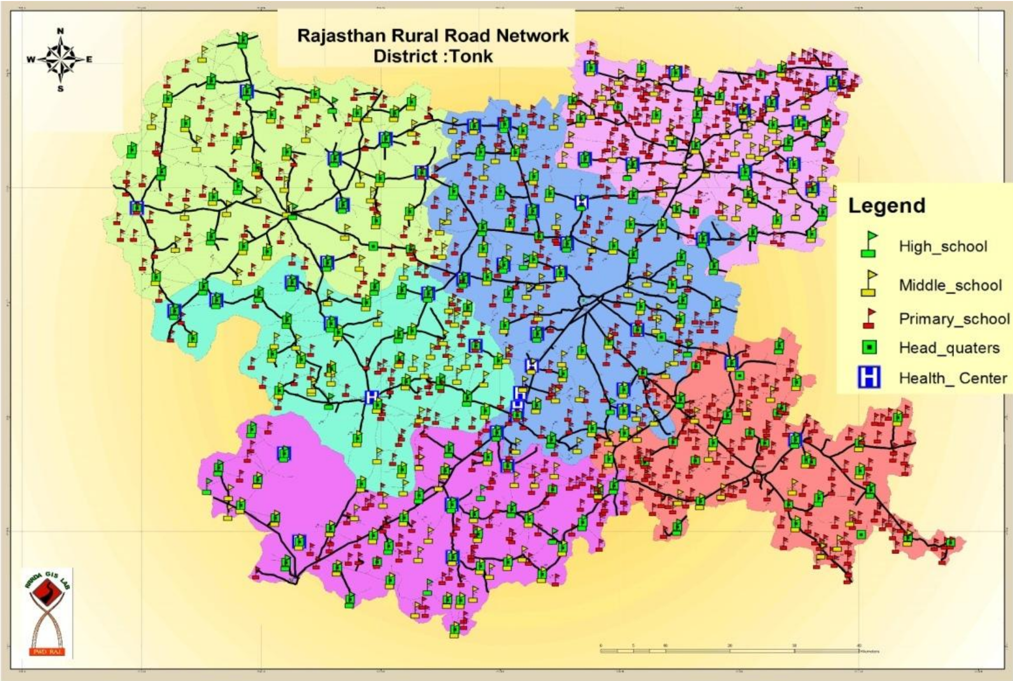


Fig 7.3. Map with Facilities Present In the Villages

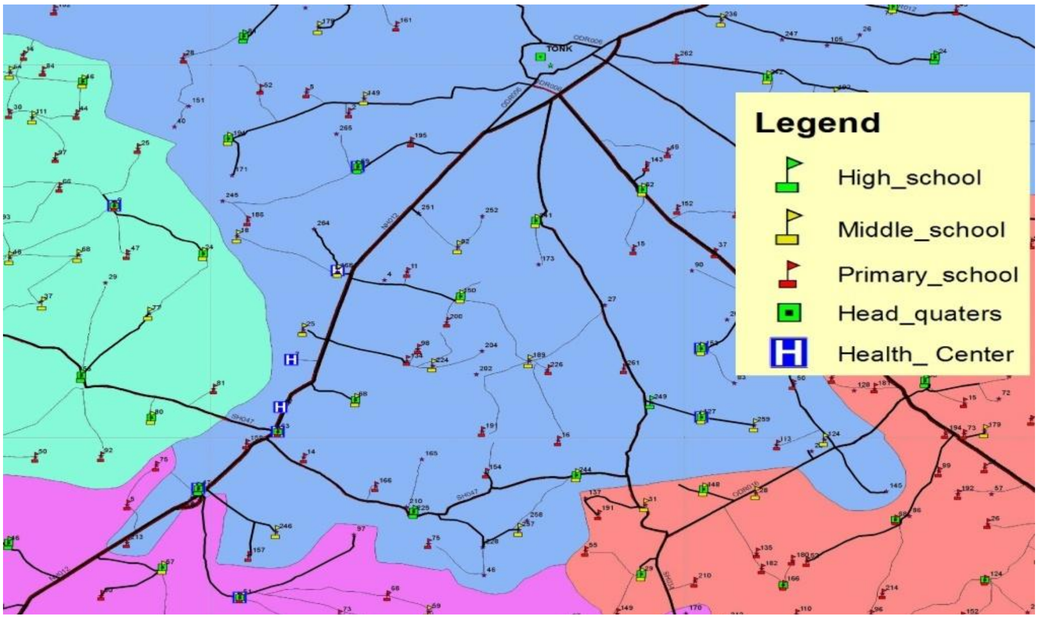


Fig 7.4. Closer View of Facilities Present in the Villages

7.2. Development of Need-Based Algorithm

The distance of travel to any facility should be within the acceptable limit as perceived by people. Hence, to determine the acceptable distance of travel, a village level informal survey was conducted in the study area with the help of local officials and NGOs. People were addressed about their tolerable and acceptable travel distance to different facilities. Accordingly, the acceptable distances to the facilities were decided as- primary school 5 km;

middle school 8 km; high school 10 km; primary health centre 8km and Panchayat headquarters 15 km.

The flowchart for developing the need-based network is shown in Fig 7.5. Using the concept of graph theory, the existing network has been presented in terms of nodes and links. The villages are represented as nodes and the road segments connecting one village to another village or to a road intersection are shown as links. Hypothetical links were also created by connecting an unconnected village with the nearby connected village or to the nearest all-weather road, whichever was found to be the shortest.

To start with an unconnected habitation was identified and checked for the facilities available within. Facilities were checked one at a time. When any of the facility was not present in the village, it was necessary to traverse from the village, link-wise, either by maximum facility algorithm or shortest path algorithm, to search for the nearest facility. In the shortest path algorithm, the villager would travel to either the nearest node or link in search of the facility through shortest path, provided the distance was within the acceptable distance. However, if another village had the particular facility and a few additional facilities which the target village did not have, the target village was connected to that village even though it did not follow the shortest path. It was ensured that the village was within the respective acceptable distances of different facilities. The process was repeated for all other facilities and also for all the unconnected villages separately to develop a network.

Each facility was given a score depending on the level of importance of the facility. Also, a particular link could be used by more than one village. Depending on the number of purposes for which a particular link was used, it was assigned a cumulative score by adding up the number of purposes for which it was used.

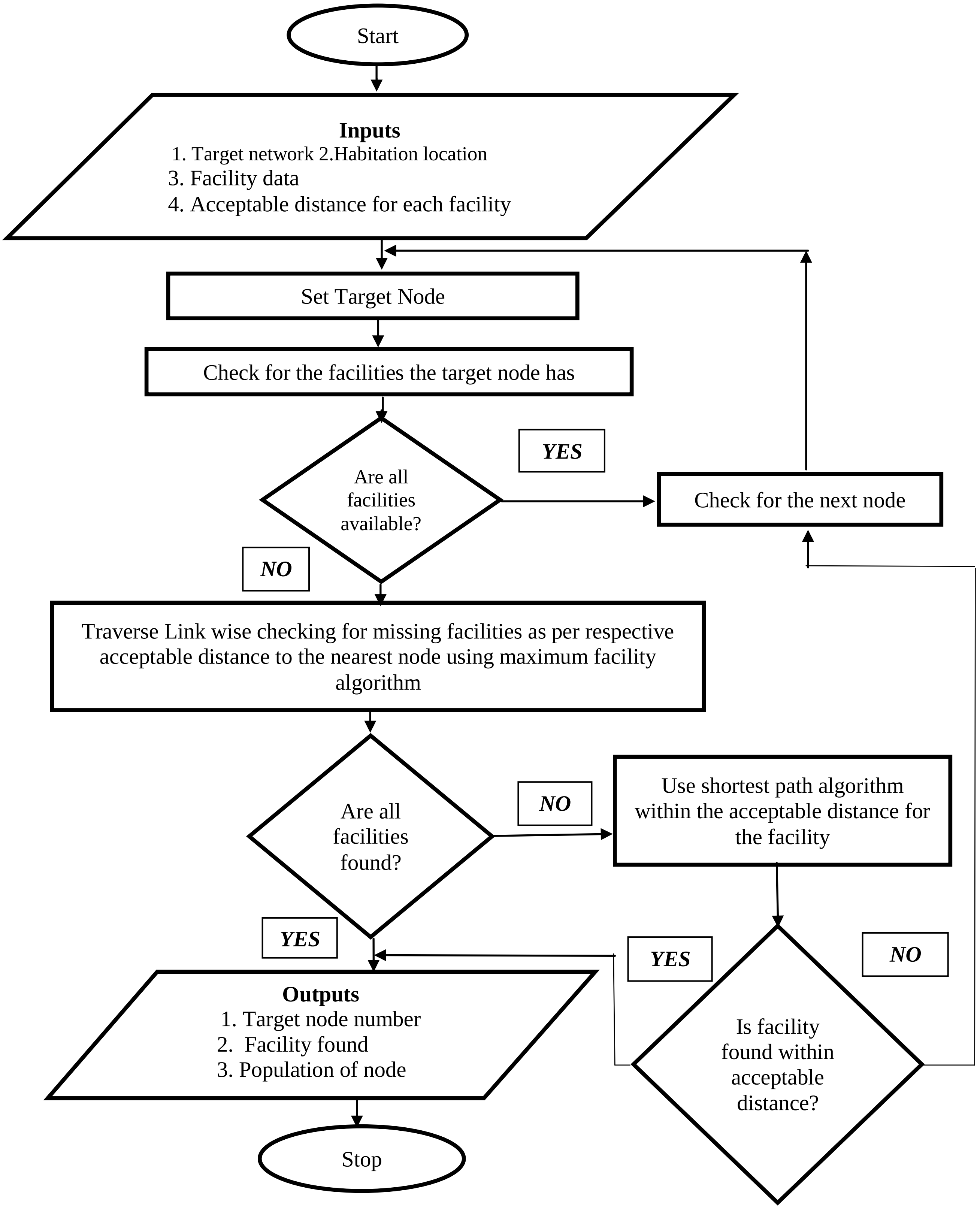


Fig 7.5. Flowchart for need-based network algorithm

According to PMGSY-II guidelines a list of 22 facilities has been classified for the up-gradation of the existing rural roads. They are: educational (Primary school, middle school, high school, pre-university course, etc.), medical (sub-centre, primary health centre, community health centre etc.), veterinary (veterinary hospital), transport and communication infrastructure (railway station, bus stand, tourist centers etc.), market (Mandi, warehouse, retail shops) and administrative (Panchayat headquarter, sub-tehsil etc.). Depending on the importance of the facilities, scores have been assigned to each one of them with a maximum possible cumulative value of 100. In the absence of data, it was not possible to include all the facilities in this study and thus only accessibility to primary school, middle school, high school, health care facilities and Panchayat headquarters have been considered. Finally, the scores were normalized so as to have a total of 100 as shown in Table7.2. Now using the steps described in Fig 7.5., for each link the number of purposes for which it was being used, total population served and the cumulative score depending on the purpose for which it was being used were calculated as shown in Table7.3.

Table 7.2. Score table of purposes

SNo.	Purpose	Score (PMGSY II guidelines)	Normalized Weightage (Max 100)
1	Primary School	3	10
2	Middle School	5	17
3	High School	7	23
4	Head Quarters	5	17
5	Health Care	10	33
	Total	**30**	**100**

Table7.3. Purposes, Total Population and Cumulative Score of Need Based Link

Link number	Number of Purpose	Total Population benefitted	Total Weight
0	5	1410	100
1	11	4514	256
2	4	702	90
3	4	3143	77
4	8	4571	189
5	5	1281	129
6	5	2478	209
7	10	4571	258
8	1	831	23
9	6	1146	114
10	3	307	66

To determine the villages which have accessibility to the facilities when connected by need-based network, the GIS network analysis tool (closest facility tool) was used. For a particular location of a facility, depending on the acceptable distance of travel, the accessible villages through the existing road network were identified. A similar exercise was done for all the facilities in the study area. Then for a particular facility location, the extremely located villages on the network were identified and were joined by lines, showing the catchment area of the facility. Next the catchment areas of all the facilities in the study area were drawn. The villages not included in the catchment areas were considered as inaccessible for that particular facility. Different shapes of catchment areas were observed depending on the acceptable distance of travel for the facility. As an example, the catchment areas of health facility have been shown in Fig 7.6.

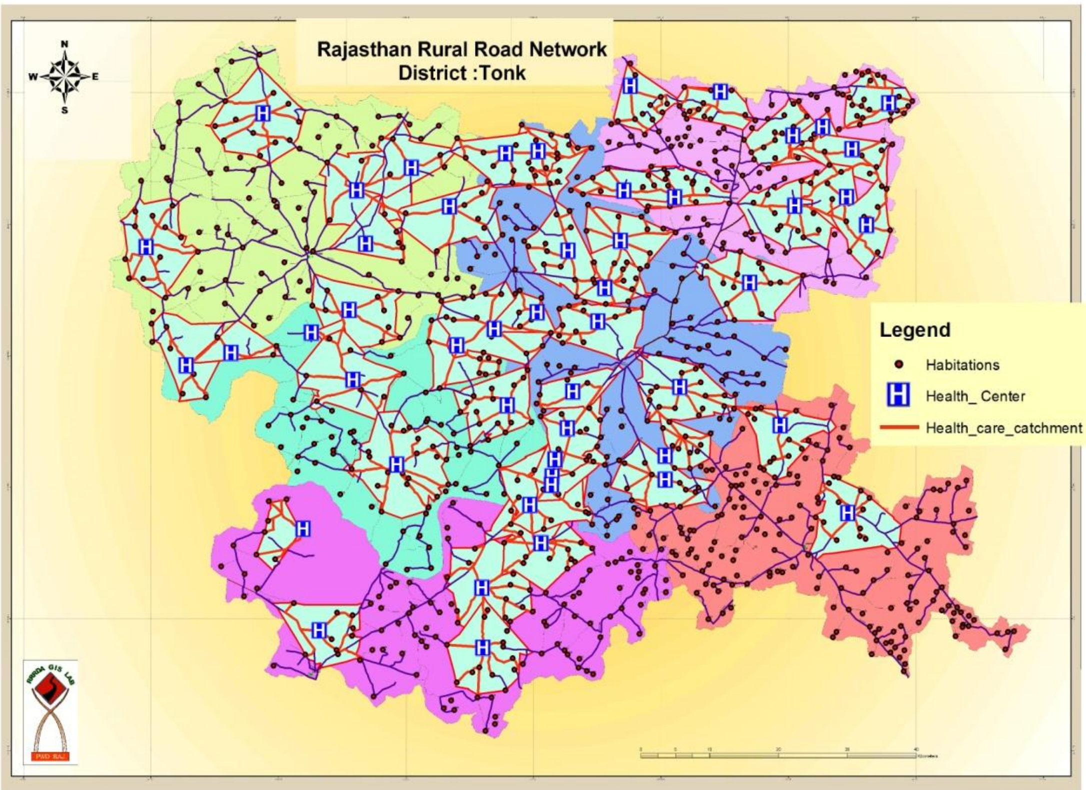


Fig 7.6. PHC Catchment Areas

From the catchment area diagram it was observed that a few villages have access to more than one similar facility because of locational advantage. These villagers have a choice and they have the advantage over other villagers who are captive to a particular facility or have access to only one facility. For calculating the size of population benefitted, if a village has access to more than one facility, the population of the village was added to all of them. This was done to identify the blocks having better overall accessibility. A block having a higher percentage of captive users obviously was at a disadvantage. The accessibility indicator (AI) for a block, was then defined as the total population having access to a facility divided by the total population of the block as shown in Eq.7.1. As it was decided to include population of all the villages being served by a facility and there was possibility of one village being served by more than one, the total number of the population having access to a facility could be more than the population of the block.

$$\text{Accessibility Indicator (AI)} = \frac{\text{Total number of population having access to a facility}}{\text{Total number of population}} \qquad (7.1)$$

The analysis was done considering the map of the year 2000 as the base as the PMGSY programme was non-existent at that time. A network was developed using need-based approach. A network using PMGSY approach of population-based connectivity was also prepared. Then a comparison was made between the two to understand the effectiveness of both the approaches. This was done in all the six blocks in the district so that it helps in finding the deficit and prioritizing the blocks. From the results shown in Table 7.4 it was clearly noticed that the overall access to PHC in the district was less. On the contrary, HQ has more number of villages which have access to more than one facility. The policy maker can take the decision accordingly to improve the accessibility of deficit block. For example, block number 6 could be targeted as it has a low AI score.

The total number of villages having a choice, villages which are captive and villages having no access are shown in Table 7.5. From the bar chart shown in Fig 7.7 it is clearly that villages which are inaccessible are high in the case of population based network when compared to need based network.

Table 7.4. Accessibility Indicators

S.No	PS		MS		HS		PHC		HQ	
	Need based	PMGSY	Need based	PMGSY	Need based	PMGSY	Need based	PMGSY	Need based	PMGSY
1	2.42	2.52	3.02	2.60	1.68	1.47	0.58	0.47	7.03	6.10
2	2.12	2.04	2.10	1.85	1.30	1.12	0.59	0.53	5.68	4.64
3	3.86	3.21	3.44	2.85	1.21	0.92	0.84	0.62	6.93	4.70
4	2.18	1.90	2.98	2.24	1.73	1.33	0.75	0.61	6.48	4.40
5	2.65	2.27	2.47	2.16	1.47	1.27	1.13	0.88	6.52	5.69
6	4.38	3.99	2.00	1.82	0.87	0.83	0.28	0.22	6.19	5.49
Total	2.87	2.59	2.66	2.26	1.38	1.17	0.74	0.59	6.47	5.22

The total length of the network created using GIS platform by population based concept is 882 km, whereas length using need based algorithm is 1174 km. However, all the links in need-based network may not be constructed by all-weather roads. Prioritization can be done based on the importance of the link, i.e., weights and the size of the population using a particular link.

Table 7.5. Comparison of Habitations benefitted by population-based and need-based methods

Type of facility	Villages having a choice		Captive Villages (accessible to one facility only)		Villages having no access	
	Need based	**PMGSY**	**Need based**	**PMGSY**	**Need based**	**PMGSY**
PS	784	730	170	208	49	65
MS	724	642	224	275	55	86
HS	286	220	456	403	261	380
PHC	83	61	426	312	494	630
HQ	980	929	18	31	5	43

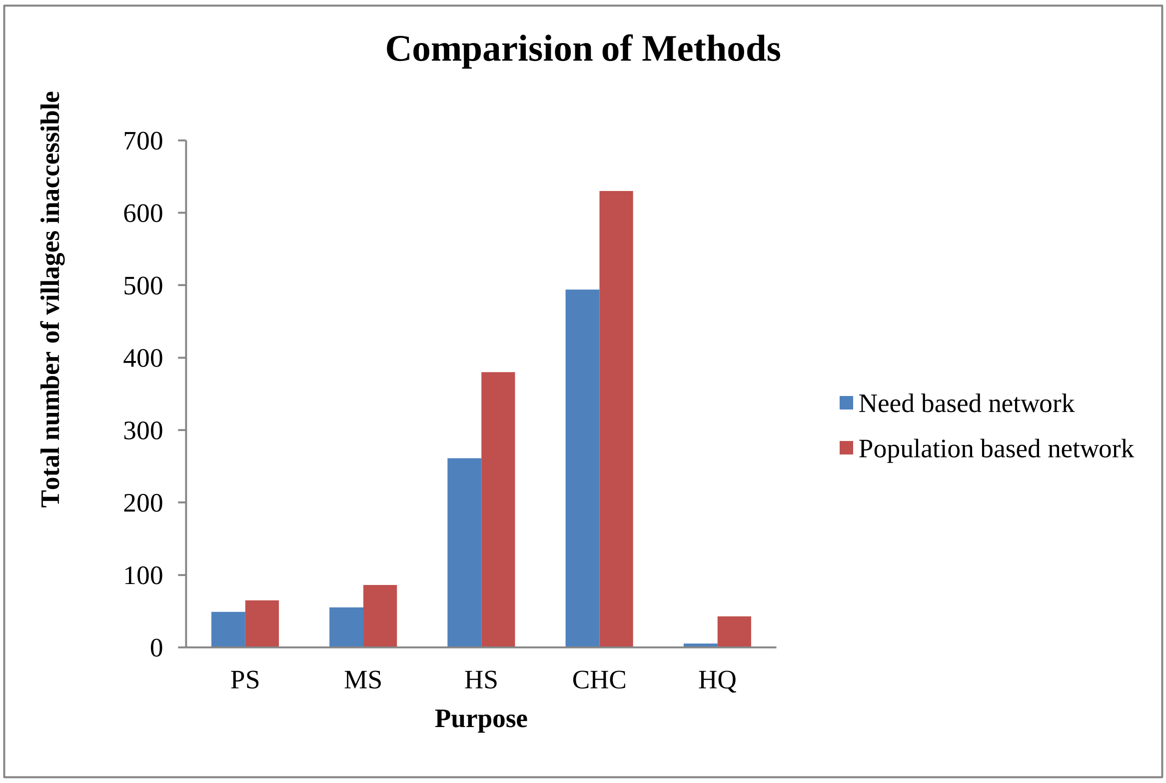


Fig 7.7. Comparison of results

7.3. Prioritization of Links

Once the network was developed based on need-based approach, it was felt necessary to develop a methodology to prioritize them for construction. From Table7.3 it has been observed that some of the links could serve a large number of populations, whereas some of them would have quite low demand. Similarly the values vary widely on the scores given on the basis of the number of purposes for which the links were going to be used. All need-based links cannot be constructed simultaneously. The policy makers will need to develop a methodology for constructing the roads depending on budgetary allocation. However, a logical methodology has been suggested in this paper based on the data available for the study. It was decided to determine the mean (μ) and standard deviations (σ) and then prioritize the links as shown in Table7.6 in descending order from A to E.

Table7.6 Range and priority order

Range	Range to score	Priority Order
Beyond $\mu+2\sigma$	>237	A
Between $\mu+2\sigma$ and $\mu+\sigma$	237-170	B
Between $\mu+\sigma$ and $\mu-\sigma$	170-103	C
Between $\mu-\sigma$ and $\mu-2\sigma$	103-36	D
Beyond $\mu-2\sigma$	<36	E

Accordingly, 31 links were categorized as priority A. Once a link was in a particular priority list further prioritization was done based on the expected population using the link. As an example priority order “A” is taken and shown in Table 7.7. The links in the same priority order are again prioritized, as A1, A2, etc. depending on population. The link with higher population is given higher priority. It might be seen in table 7 that link No. 340 has been given the first priority, A1, in spite of having a lesser score than many other links in the category because the highest number of population is expected to get benefits through the link. It was felt during the study that all the links need not be constructed as a high quality road such as blacktop or concrete. The links having lower values could be constructed as gravel or earth road as well. This might be decided based on the scores and the population. However, determination of the threshold values was not within the scope of this study.

Table 7.7. Ranking and priority order of the link

Link No.	Population	Score	Rank	Priority
340	7249	244	A	A1
601	5858	336	A	A2
470	5329	258	A	A3
467	4627	241	A	A4
685	4588	264	A	A5
7	4571	258	A	A6
239	4528	265	A	A7
1	4514	256	A	A8
328	4285	248	A	A9
576	4069	386	A	A10
577	4069	406	A	A11
578	4069	406	A	A12
722	3941	249	A	A13
500	3665	572	A	A14
238	3623	280	A	A15
703	3595	265	A	A16
135	3451	388	A	A17
313	3417	273	A	A18
270	3384	264	A	A19
567	3255	390	A	A20
597	3186	258	A	A21
326	3181	257	A	A22
715	2996	333	A	A23
97	2625	326	A	A24
98	2625	438	A	A25
629	2547	246	A	A26
100	1961	280	A	A27
320	1942	280	A	A28

7.4 SUMMARY

In the present chapter, the various steps involved in the development of need based approach for road connectivity have been discussed. To find the effectiveness of the methodology proposed the need based approach was compared to the PMGSY approach of population-based connectivity network. Also the prioritization technique for ranking the road links for construction have been presented.

Chapter 8

Findings, Conclusions, Recommendations and Scope for further Study

8.1. Introduction

Many of the developing countries such as India have failed to provide access to basic facilities in rural areas due to lack of adequate funds and the absence of focused goals for improving accessibility. In the PMGSY programme launched in 2000, efforts have been made to improve accessibility in rural areas. However, keeping in view the shear number of villages to be connected, there is a long way to go before total accessibility could be achieved. To identify the needs in different regions, a quantifying tool, RAI developed by IDA has been widely used in the developing countries. The method has been applied in five districts of Rajasthan in this study. However, overall accessibility index does not reflect the actual accessibility of villages to the basic and other needs due to the construction of roads. Thus a methodology to quantify accessibility at habitational level was developed in this study that includes all the parameters that reflects the true accessibility values including quality of service provided. From both the measures, it has been observed that many habitats are inaccessible. Keeping the fact in view that a planning from the network level will boost overall accessibility in a region, a need based network for road connectivity in rural areas. Moreover, in this study impact of road construction on accessibility to all weather roads is also found using the same technique adapted for regional level analysis. The following are the general finding from the present research work.

8.2. General Findings

- At the regional level analysis it was observed that accessibility varies with population density. Higher the population density, higher the accessibility and in contrary for less population density regions accessibility is low.
- Total road length required for connecting habitations and the population density are inversely related, i.e., if the population density is high, lesser length of road construction is required to connect the habitations.

- Block-wise analysis of all the five districts shows that the construction of PMGSY roads has substantial impact on improving over-all accessibility ranging between 9.1% to 32.07%. District-wise analysis shows that the impact is ranging between 17.81% and 21.16%.
- The impact of construction of PMGSY roads on overall accessibility is more when calculated using PMGSY definition as a part of comparison to the IDA definition as most of the all-weather roads constructed by PMGSY are less than 2 km.
- Percentage increase in accessibility per kilometer of road length construction is greater in densely populated areas.
- Even though two-step floating catchment area (2SFCA) method and enhanced two step floating catchment area (E2SFCA) method has been used successfully in urban areas in many countries, they were not found effective in rural areas in this study for determining accessibility to CHC.
- Even the government of India has stated that the present average radial distance travel to reach CHC is 15 km it has been noticed that as the population density decreases people are forced to travel for more than 15 km to get the service. In some isolated desert region they even travel upto 35 km.
- When compared to males, females have a higher opinion on the quality of CHC in general.
- While connecting habitations based on need based approach in Tonk district it has been observed that the total length of the network is higher compared to population-based approach.
- From the results obtained for all the districts using M2SFCA method, it has been observed that the maximum accessibility Index was found in Bikaner district and minimum was found in Alwar.
- From the travel data collected, it was observed that with distance the number of patients visiting a health centre decreases gradually.
- From the individual travel behaviour, it has been observed that people walk if the distance is less than 2.5 km. If the individuals travel for more than 2.5 km to reach health care they use car, taxi or public transport and sometime cycle.

8.3. Conclusions

In the present study, an attempt has been made to develop methodologies to quantify accessibility at different levels. Also a need based approach has been developed for rural road connectivity to improve access to basic facilities. Accordingly, a case study was conducted in five districts of Rajasthan with varying population density. On the basis of the study the following conclusions have been drawn.

- The number of habitations with no accessibility increases significantly with the decrease in population density of the region. Also the percentage increase in accessibility per kilometer of construction of the road is higher in densely populated areas.
- The construction of new roads based on population criteria as used in PMGSY programme increases the overall accessibility in the region. However the impact is more in areas with high population density.
- The method proposed in the study is able to quantify accessibility of health facilities with special reference to CHC quite satisfactorily as the results have been validated.
- While the fitting impedance function, it has been observed that sigmoidal functions like logistic power and MMF are more likely suitable for the high population density regions and also plain terrains. Though decline functions and rational models can be used for low population density regions and difficult desert or hilly areas.
- Besides the usual parameters such as supply, demand and travel distance considered by various researchers for determining accessibility to health care, the contributions of mobility and quality of service provided by CHC and type of road to be travelled are quite influential in quantifying accessibility.
- The perception of females and males on quality of service provided by the CHC is significantly different.
- The need-based rural road network planning approach proposed in this study ensures accessibility to the needs of the rural population.
- The need-based approach requires more road length compared to population based approach. However, the total cost may be optimized by suggesting different surfaces depending on the demand pattern.

8.4. Recommendations

The following are some of the recommendations based on the experiences gained from the present research work.

- Policy Decision makers may use the quantification techniques proposed in this study before making any major investment's for enhancing accessibility in a region.
- The priority list obtained using PMGSY and IDA indicators may be used for improving accessibility in less accessible regions.
- A model developed between travel distance and travel time would predict the travel time with good accuracy in the study area.
- A model developed between travel distance and travel cost parameters would predict the travel cost with good accuracy in the study area.
- The need-based approach developed for connecting habitations with small population can help policy makers to achieve total accessibility with optimized cost. It also suggests the kind of surface to be provided for each link.

8.5. Scope for further research

While concluding the study, it was found that certain aspect of the study needs further attention. Those are presented below.

- Accessibility to all the sectors to which rural individuals travel to meet their needs could not be quantified and a composite level of accessibility for each habitation separately.
- Indian rural health care Infrastructure system is developed as a three tier system includes Sub center, Primary health care center and Community health care center. A composite accessibility for health sector may be determined.
- The threshold distance considered in this study is sensitive with respect to development and geographical characteristics of the region, therefore there is a scope to do sensitivity analysis.
- The need based approach developed has been applied to the plain terrain area. There is scope to study the applicability of this method in hilly regions, to check its robustness.

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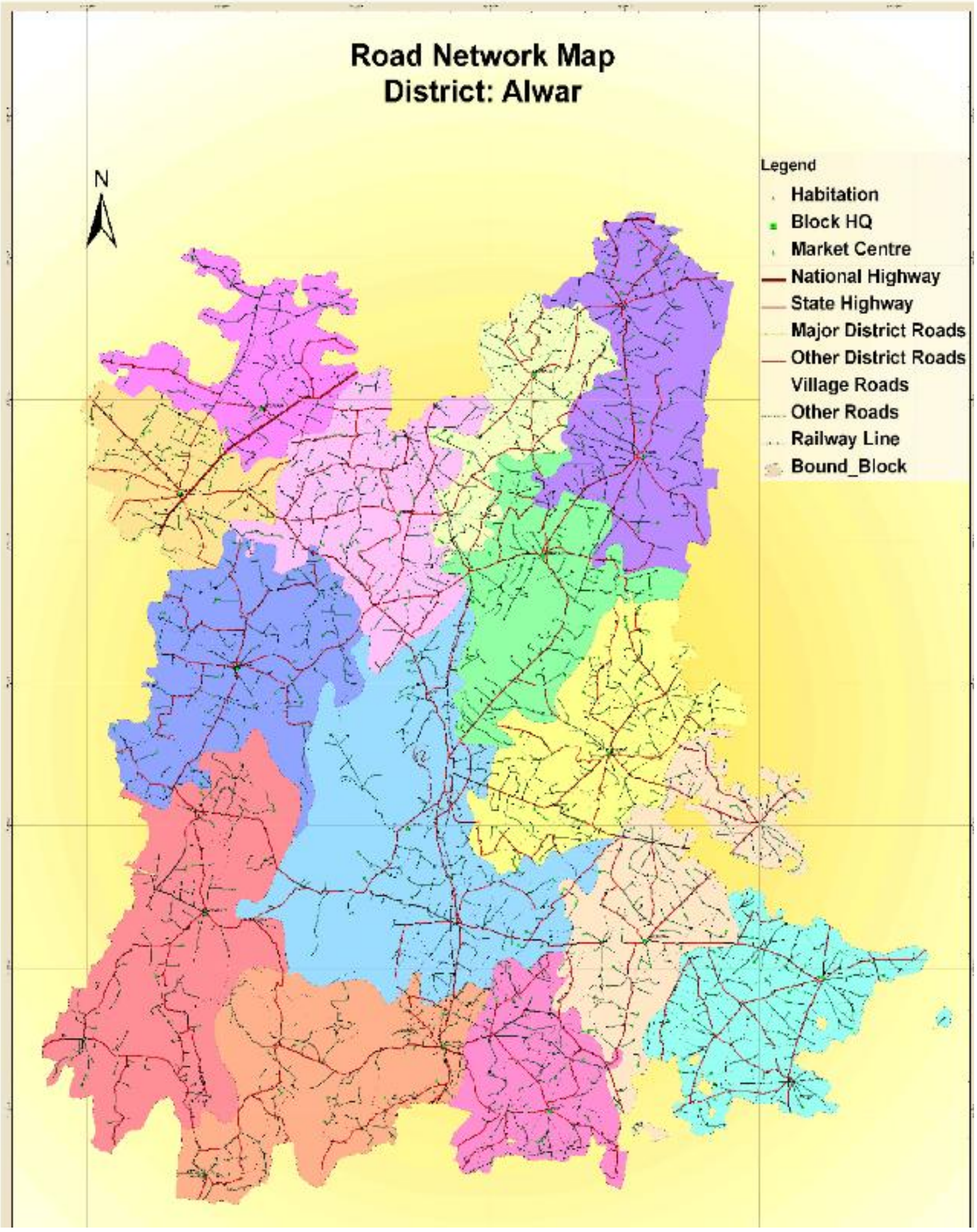
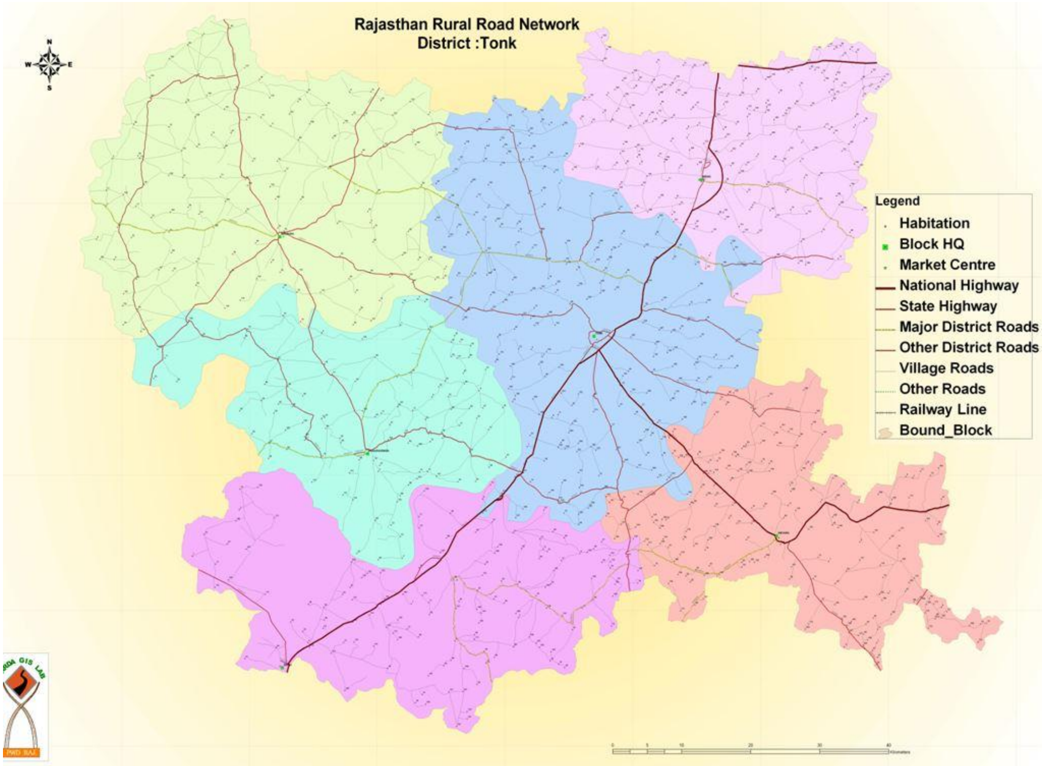
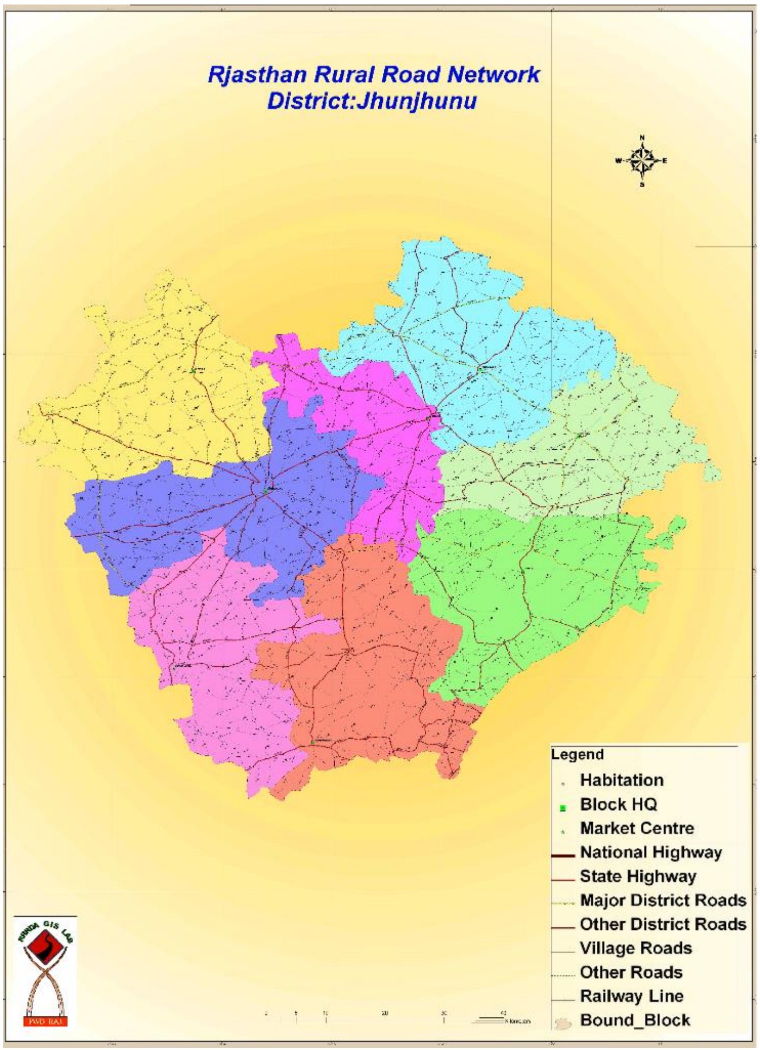
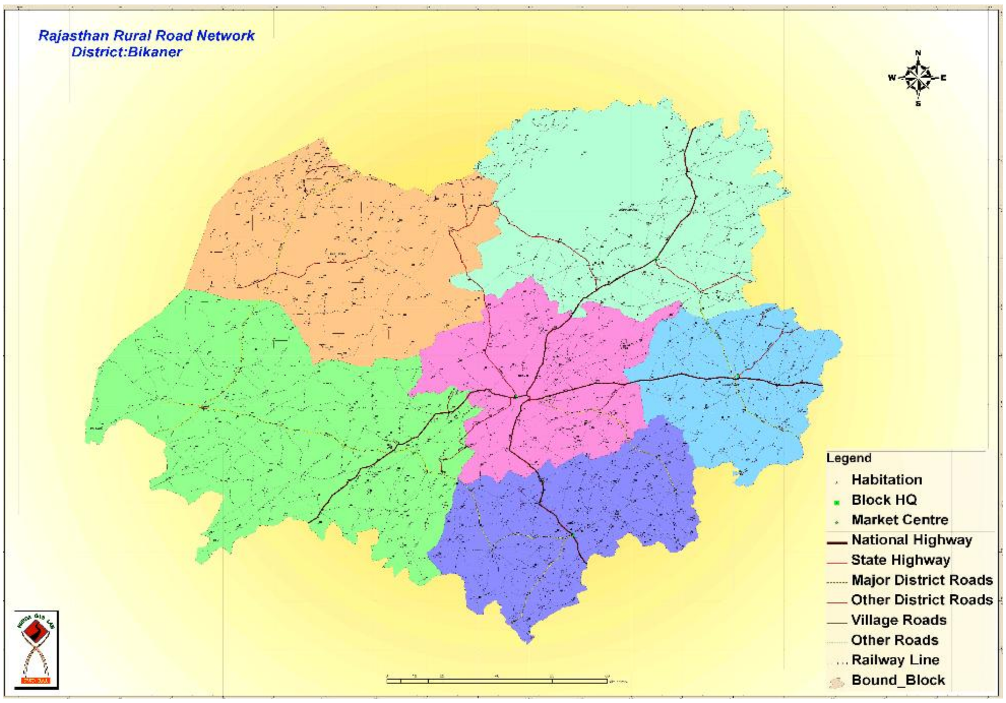
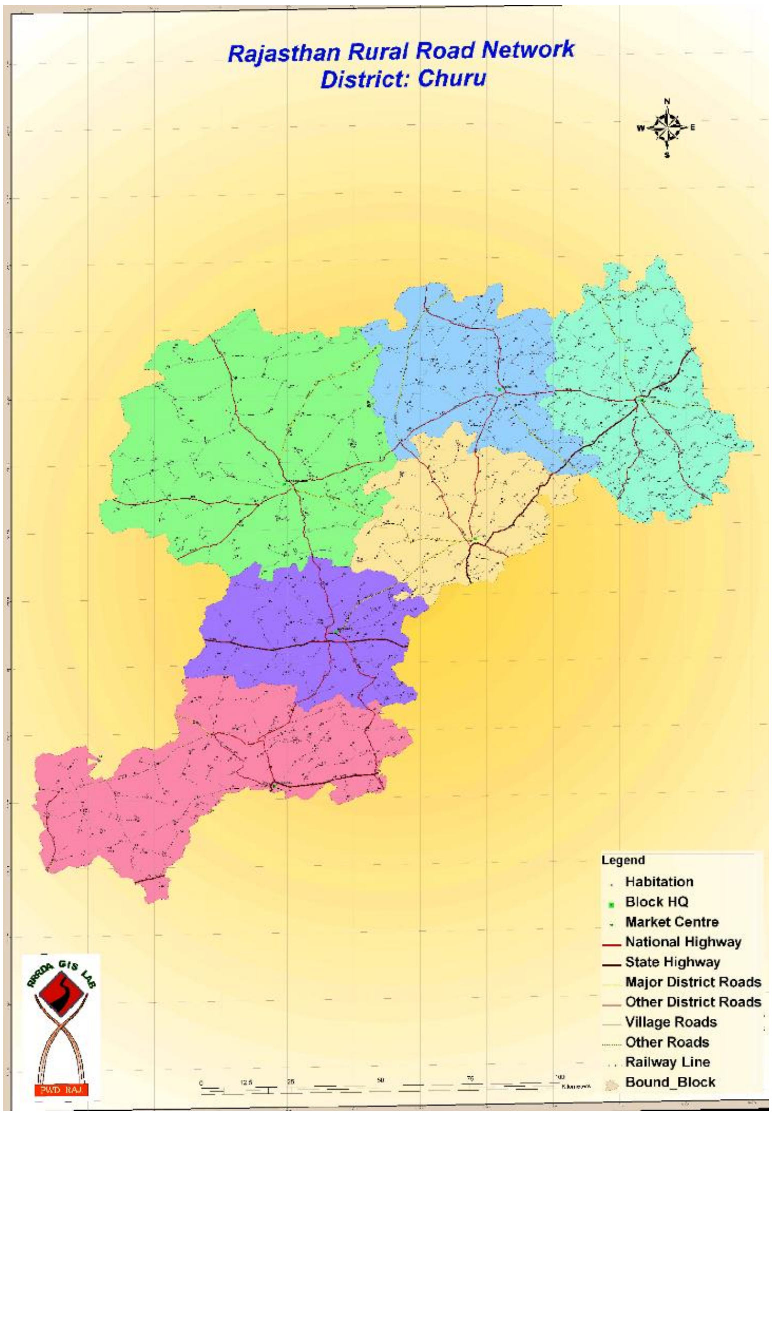
Appendix-1: Road Network Maps




Rajasthan Rural Road Network
District :Tonk
Legend
Habitation
Block HQ
Market Centre
National Highway
State Highway
Major District Roads
Other District Roads
Village Roads
Other Roads
Railway Line
Bound_Block


Rjasthan Rural Road Network
District:Jhunjhunu
Legend
Habitation
Block HQ
Market Centre
National Highway
State Highway
Major District Roads
Other District Roads
Village Roads
Other Roads
Railway Line
Bound_Block


Rajasthan Rural Road Network
District:Bikaner
Legend
Habitation
Block HQ
Market Centre
National Highway
State Highway
Major District Roads
Other District Roads
Village Roads
Other Roads
Railway Line
Bound_Block


Rajasthan Rural Road Network
District: Churu
Legend
Habitation
Block HQ
Market Centre
National Highway
State Highway
Major District Roads
Other District Roads
Village Roads
Other Roads
Railway Line
Bound_Block

Appendix-2: Out Patient Details collected from BUHANA Community Health Centre

OPD Details from BUHANA Community Health Centre for the Month of NOVEMBER 2014																																
Village	**D**	**No. of Patient in NOVEMBER 2014**																														**T**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
Buhana	0	20	5	30	53	48	89	74	81	15	73	66	91	101	93	97	25	4	83	51	66	78	73	29	98	89	61	57	73	99	113	1935
Jhanjha	5	5	2	2	3	0	2	5	3	1	0	4	3	3	2	0	4	0	3	1	0	1	1	2	2	4	3	2	0	3	1	62
Khandwa	7	3	1	4	3	2	0	4	1	2	1	0	3	1	1	1	0	1	1	2	2	1	0	3	2	0	2	2	1	3	1	48
Ghaseda	10	2	2	3	1	2	1	2	3	1	2	4	2	1	2	1	3	2	4	2	3	2	3	1	4	3	2	3	2	1	2	66
Sangwa	8	4	1	4	2	0	3	0	2	3	2	1	2	0	3	2	1	2	1	3	2	1	0	2	4	2	3	0	4	5	4	63
Hasas	4	5	1	2	3	1	3	2	1	2	0	3	2	2	0	1	2	3	2	0	1	3	2	1	0	3	1	2	4	3	2	57
Dhakamandi	5	9	0	3	0	1	0	2	0	1	3	2	4	5	2	0	3	1	3	2	1	2	1	1	2	3	0	4	5	0	3	63
Kuhadwas	10	6	1	2	2	2	3	1	2	2	2	3	0	1	2	5	0	2	0	1	2	3	2	0	2	4	3	2	0	1	5	61
Rambas	10	5	0	4	1	0	1	2	4	1	1	2	1	0	2	0	2	1	3	2	1	0	4	2	0	1	3	2	1	2	0	48
Nanbas	12	4	0	5	3	3	1	0	2	3	1	0	2	1	2	0	1	1	2	1	3	2	1	0	2	0	1	0	3	2	1	47
Lalamandi	10	3	2	3	2	3	2	1	3	2	1	1	0	1	0	1	1	1	1	1	0	2	0	0	1	0	2	4	0	1	2	41
Udamandi	11	4	1	2	0	2	3	1	2	1	1	1	1	0	1	0	1	3	2	1	0	2	0	2	3	2	1	2	3	0	3	45
Bhirr	8	5	0	4	1	1	0	4	0	2	0	2	0	0	0	2	1	3	2	1	2	3	0	2	0	2	3	0	1	2	1	44
Balawas	6	6	0	3	2	1	2	1	4	2	2	3	1	2	0	1	0	3	3	0	3	2	1	1	1	3	4	2	1	3	3	60
Sahad	7	8	0	3	1	0	3	1	2	3	1	0	1	2	2	2	2	4	2	1	3	2	1	2	2	1	2	3	0	1	0	55
Manpura	3	7	1	4	0	1	4	0	2	1	3	1	2	1	1	0	3	3	0	2	1	0	4	4	0	2	3	1	0	2	4	57
Kalakhari	5	6	1	5	3	2	1	3	2	1	3	2	4	3	2	0	3	3	4	2	1	2	1	3	3	5	4	3	2	1	2	77
Palota	4	2	2	6	1	1	0	4	0	1	0	0	1	2	0	3	2	1	0	2	1	0	2	2	3	2	0	1	4	2	5	50
Shyampura	7	4	1	4	4	2	2	3	2	2	3	0	1	2	4	0	3	1	2	0	3	2	4	1	3	0	1	2	1	0	3	60
Mainana	7	3	2	5	0	1	4	2	1	3	2	1	1	1	2	1	0	3	4	2	0	1	2	2	0	1	2	2	3	2	1	54
Sultana	4	2	1	7	2	2	5	0	0	2	2	1	3	0	2	1	1	2	3	2	1	2	1	2	2	0	3	2	0	1	4	56
Jaisinghpura	4	4	2	3	3	0	2	1	0	2	0	2	1	3	2	1	2	3	2	0	1	2	3	0	1	2	4	0	2	3	0	51
Badbar	6	5	1	2	4	1	3	5	1	1	2	1	0	4	2	0	1	2	1	3	2	1	3	1	2	3	2	1	4	2	5	65
Chouradi	8	6	2	4	4	2	0	2	1	2	0	2	1	8	3	5	2	1	0	4	2	0	3	3	1	2	0	3	0	2	6	71

D- Distance; T-Total

Appendix-3

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI

Community Health care Infrastructure and Staffing Pattern

August – November 2014

Date:........................ Village:......................... Block: ………… District……………

Community Health Centre		
A.	**Personnel**	**Clinical Manpower**
1	Block Health Officer	
2	General Surgeon	
3	Physician	
4	Obstetrician / Gynaecologist	
5	Paediatrics	
6	Anaesthetist	
7	Public Health Manager	
8	Eye Surgeon	
9	Dental Surgeon	
10	General Duty Medical Officer	
11	Specialist of AYUSH	
12	General Duty Medical Officer of AYUSH	
13	Others	
B.	**Personnel**	**Support Manpower**
1	Staff Nurse	
2	Public Health Nurse	
3	ANM	
4	Pharmacist / compounder	
5	Pharmacist - AYUSH	
6	Lab. Technician	
7	Radiographer	
8	Ophthalmic Assistant	

Community Health Centres				
S.No.	**Physical Infrastructure**	**Yes**	**No**	**Comments**
1.	Buildings			
2.	Prominent display board in local language			
3.	Availability of drinking water			
4.	Separate toilets for men and women			
5.	Pharmacy			
6	Functional labour room			
7.	Functional laboratory			
8.	X-Ray room with dark room facility			
9.	Operation theater			
10.	Good condition of floors			
11.	Good cleanness in OPD premises			
12.	Good cleanness in OT			
13.	Good cleanness in wards			
14.	Good cleanliness in premises			
15.	Others			

S.No.	Service Facilities	Yes	No	Comments
1.	24 hrs delivery services including normal and assisted deliveries			
2.	Emergency obstetric care, caesarian and other surgical medical intervention			
3.	Emergencies care of sick children			
4.	Full range of family planning services including laparoscopic services			
5.	Safe abortion services			
6.	Treatment of STI/RTI			
7.	Referral transport services			
8.	Separate wards for male/female			
9.	Pediatric Beds			
10.	Counseling for HIV/AIDS/STD			
11.	Voluntary Counseling			
12.	Antenatal services			
13.	Post natal services			
14.	Immunization Sessions			
15.	Is separate septic room available			

S.No.	Service Facilities	Yes	No	Comments
16.	Out-patient department in Gynecology/obstetric			
17.	Rogi Kalyan Samiti			
18.	Others			
S.No.	**Lab Facilities**	**Yes**	**No**	**Comments**
1.	Availability of ECG currently at CHC			
2.	X-Ray facilities currently at CHC			
3.	Ultrasound facilities currently at CHC			
4.	Availabilities of specific lab test facilities			
5.	Others			

Comments:

Appendix-4

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI

Quantification of Accessibility to health care in Rural Rajasthan

August – November 2014

(Village –level questionnaire survey)

Date: ……………… Village: .... Block: ………………. District ………………

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1. General Information

Give the population details of the village:

Population	Number of households	Number of population			Others
		Scheduled Caste	Scheduled Tribe	OBC	

Approximately how much percentage of villagers are involved in each of the following professions?

Profession	Number of Villagers
Marginal farmer (up to 2.5 acres)	
Small farmer (2.5 to 5 acres)	
Large farmer (over 5 acres)	
Agricultural labourer	
Government job	
Private job	
Self employed	
Unemployed	
Any other:	
Any other	

Number of households owning vehicles:

Mode	Number of household owning
Bicycle	
Donkey cart	
Camel cart	
Buffalo/ Ox cart	
Two-wheeler	
Jeep/ car	
Tractor	
Any other	

2. Perception of villagers on Community Health centre (CHC)

1. Waiting time (min)

[ ] Less than 30 [ ] 30-60 [ ] 60-90 [ ] 90-120 [ ] More than 120

2. Availability of Physician

[ ] Available for 24 hrs [ ] Available for 12 hrs [ ] Available for 6 hrs

[ ] Available for 3 hrs [ ] Not available

3. Availability of Medicine

[ ] Available for 24 hrs [ ] Available for 12 hrs [ ] Available for 6 hrs

[ ] Available for 3 hrs [ ] Not available

4. Conduct of Physician

[ ] Very good [ ] Good [ ] Fair [ ] Satisfactory [ ] Poor

5. Overall satisfaction with the services provided by CHC

[ ] Highly Satisfied [ ] Satisfied [ ] Undecided [ ] Dissatisfied

[ ] Highly dissatisfied

Importance rating on the following parameters

1. Waiting time

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

2. Availability of Physician

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

3. Availability of Medicine

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

4. Conduct of Physician

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

3. Mobility to Community Health center (CHC)

Acceptable distance to reach CHC …………………………………….

1. Satisfaction level of present accessibility to CHC

[ ] Highly Satisfied [ ] Satisfied [ ] Undecided [ ] Dissatisfied

[ ] Highly dissatisfied

Importance rating on the following parameters

1. Travel time

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

2. Travel cost

[ ] Very important [ ] Important [ ] Undecided [ ] Not important

[ ] Not very important

Travel Information

Access Road	**Location**	**Distance**	**Kind of road**	**Quality of road***	**Usual mode of travel**	**Travel time (min)**	**Travel cost (Rs.)**
1							
2							
3							

*On a scale of 1 to 5, 5 represents very good, 4-Good, 3- Satisfactory, 2- Poor and 1- Very poor

Approximate time taken by different kinds of modes to reach the nearest all-weather road from where other transport modes are available

Mode	**Time Taken**	**Travel cost**	**Waiting time(if public transport)**
Bicycle			
Two wheeler			
Tempo			
Car/Jeep			
Bus			
Tractor			
Other			

4. Specify the comments you would like to make on any other aspects on accessibility related problems that have not been covered in the questionnaire:

----

5. Rough sketch of the location of the village with reference to other villages/ town, all- weather roads and nearest public transport stop:

Appendix-5: MATLAB programme for calculating accessibility using 2SFCA method

```
clear all
load('2SFCA_Normal_Input_Output.mat')
for i=1:size(f,1)
d1=find(data(:,3)==f(i,1));
d2=find(data(:,2)==f(i,1));
f(i,2)=1;
f(i,3)=sum(data(d2,5));
f(i,4)=f(i,2)/f(i,3);
end
for i=1:2217
a=[ ];
d3=find(data(:,3)==i);
a=data(d3,2);
if ~isempty(a)
a2=0;
for j=1:length(a)
a1= f(f(:,1)==a(j),4);
a2=a2+a1;
end
else
a2=0;
end
f1(i,[1 2])=[i a2];
end
```

Appendix-6: MATLAB programme for calculating accessibility using E2SFCA method

```
clear all
load('E2SFCAM.mat')
a=[ ];
o2=f;
for i=1:size(f,1)
d1=find(data(:,3)==f(i,1));
d2=find(data(:,2)==f(i,1));
o2(i,3)=sum(o1(d2,5).*o1(d2,6));
o2(i,4)=o2(i,2)/o2(i,3);
end
for i=1:2217
a=[ ];
d3=find(o1(:,3)==i);
a=o1(d3,2);
b=o1(d3,6);
c=o1(d3,7);
d=o1(d3,8);
if ~isempty(a)
a2=0;
for j=1:length(a)
a1= o2(f(:,1)==a(j),4).*b(j);
a2=(a2+a1).*c(j)*d(j);
end
else
a2=0;
end
o3(i,[1 2])=[i a2];
end
```

Appendix-7: MATLAB programme for calculating accessibility using M2SFCA method.

```
clear all
load('SE2SFCAM.mat')
a=[ ];
o1=data;
for i=1:size(f,1)
d1=find(data(:,3)==f(i,1));
d2=find(data(:,2)==f(i,1));
o2(i,3)=sum(o1(d2,5).*o1(d2,6));
o2(i,4)=o2(i,2)/o2(i,3);
end
for i=1:2000
a=[ ];
d3=find(o1(:,3)==i);
a=o1(d3,2);
b=o1(d3,6);
c=o1(d3,7);
d=o1(d3,8);
if ~isempty(a)
a2=0;
for j=1:length(a)
a1= o2(f(:,1)==a(j),4).*b(j).*c(j)*d(j);
a2=(a2+a1);
end
else
a2=0;
end
o3(i,[1 2])=[i a2];
end
```

List of Publications

Journals

1) Kanuganti, S., Sarkar, A. K., Singh, A. P., & Arkatkar, S. S. (2014). Quantification of Accessibility to Health Facilities in Rural Areas. Case Studies on Transport Policy. Elsevier publication. Vol(3) 3, pp 311-320.
2) Kanuganti, S., Sarkar, A. K., Singh, A. P, (2014) “Quantifying Accessibility to Health Care using Two-step Floating Catchment Area Method (2SFCA): A case study in Rajasthan” Procedia-Social and Behavioral Science, Elsevier publication. (Accepted)
3) Kanuganti, S., Dutta, B., and Sarkar, A. K., (2015) “Development of a Need-Based Approach for Road Connectivity in Rural Areas”, Applied Geography **(Under review)**
4) Kanuganti, S., Sarkar, A. K., and Singh, A. P, (2015) “An modified two-step floating catchment area (M2SFCA) method for measuring accessibility to health care in rural areas”, Health and Place. **(Under review)**
5) Kanuganti, S., Sarkar, A. K., and Singh, A. P, (2015) “Evaluation of access to health care in rural areas using Enhanced two-step floating catchment area (E2SFCA) method”, International Journal of Health Geographics. **(Under review)**
6) Kanuganti, S., Sarkar, A. K., and Singh, A. P., (2015) “Impact of construction of PMGSY roads on accessibility in rural areas”, IRC Journal. **(Under review)**

Conferences

1. Kanuganti, S., Sarkar, A. K., Singh, A. P, “Impact of PMGSY roads on Rural Accessibility: A case study in Rajasthan”, National Seminar on Geoinformatics Applications in Rural Development, 26-27 March, 2015, NIRDPR, Hyderabad.
2. Kanuganti, S., Bhupali Dutta and Ashoke Kumar Sarkar "Development of a Need-Based Approach for Road Connectivity in Rural Areas", 94th Annual meeting of Transportation Research Board, 11-15 January 2015, Washington, D.C.
3. Kanuganti, S., Sarkar, A. K., Singh, A. P, Quantifying Accessibility to Health Care using Two-step Floating Catchment Area Method (2SFCA): A case study in Rajasthan. Proceedings of the International Conference - 11th TPMDC, 10-12 December, 2014, IIT Bombay.

Brief biography of the Candidate

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Brief biography of the Co-Supervisor

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