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THESIS NO:

MEDIAN BASED APPROACH FOR LOCATING WARD CENTERS; A CASE STUDY OF TRIBENI RURAL MUNICIPALITY OF ROLPA DISTRICT

BY

GOPI RAJ PUN MAGAR

071/MST/254

A THESIS

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The undersigned certify that they have read, recommend to the Institute of Engineering for acceptance, the thesis entitled "Median Based Approach for location Ward Center: A case study of Tribeni Rural Municipality of Rolpa District" submitted by Gopi Raj Pun Magar (071/MST/254) in partial fulfillment of the requirements for the award of the degree of Master of Science in Transportation Engineering.

____

Supervisor, Dr. Jagat Kumar Shrestha

Associate Professor

Department of Civil Engineering, Pulchowk Campus

____

External Examiner, Prof. Dr. Padma Bahadur Shahi

Technical Advisor, Department of Transport Management

____

Committee Chairperson, Er. Anil Marsani

M. Sc. in Transportation Engineering

Department of Civil Engineering, Pulchowk Campus

Date:

ABSTRACT

Access to ward centers from settlement is important which plays significant role in saving the time of people. Especially in rural areas where settlement are more scattered and population density is low, ward center location plays a vital role for service delivery. The ward center locations from which the services are delivered in Nepal are not optimized to serve demand points i.e. settlement. In most of the cases ward centers are either in existing VDC Center or selected on ad-hoc basis.

This research aims at the study the relationship between number of ward centers and population distance. For this study, Tribeni Rural Municipality of Rolpa district has been taken into consideration where there are seven existing ward centers to serve the population of 24,859. One hundred forty settlements (villages) are found which is treated as demand point and ward centers are service centers. P-Median model using python programming (with pulp library) is used to solve this location problem.

In Tribeni Rural Municipality currently there are seven ward centers with average weighted distance of 3.6 km. We can vary the ward centers from five to twenty one as per the legal provision of Nepal, average weighted distance decreases from 4.38 km to 1.83 km.

Key Words: *Population Distance, Ward Center, P-Median Model, Rural Municipality, Settlement*

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

Chapter 1 Introduction

1.1. Background of the study

Service facilities provide services to the public. It includes education, health care, transportation, social welfare and security and so on. Service facilities provide services for the basic need and for the development of people; therefore the location of facilities affects directly the fairness.

In the ancient time, decisions of location were usually based on experience which was excessive subjectivity and lack of scientific foundation. The modern location problem was first proposed by (Weber, 1909). In his research, objective was to locate a warehouse with the aim of minimizing the carriage distances between warehouse and customers. After the success of this paper researchers started to solve facility location problem based on science and it would definitely bring positive influence on social development.

Facility location is a long-term, strategic decision which has great impacts on both social organizations and human activities. The quality of facility location decision influences service methods, service quality, service efficiency and the cost of service. Correct facility location decision will bring convenience to people's life, reduce costs expand the social welfare. While incorrect decision always leads to inconvenience to the people. Nowadays, the problem of facility location is related to many aspects, such as technical, economic, political, cultural and social. The study of facility location is significant for both public service facilities and private facilities.

Location of service facilities is an issue of planning and development. The harmony between human demand and service supply is directly linked. In this study, a location-based study of Rural Municipality service is performed as an example. Its purpose is to achieve a reasonable allocation of service facilities, so that the public could benefit.

1.2. Rural Accessibility

Rural accessibility is a key issue in many parts of the world. Accessibility to services (Administrative, health, schools, market Center) for rural populations is a goal of most governments in developing countries. Almost 45% percent of the world's population lives in rural areas and in case of Nepal rural population was reported at 80 % in 2018, according to the World Bank.

Service delivery in rural areas is more costly because of lower density populations and larger distances that have to be travelled by people towards service centers. It is estimated that about 900 million rural people in developing countries do not have reliable all season access to main road networks, and about 300 million people do not have motorized access at all (Jerry Lebo, 2001). The rural people have isolation, exclusion, and unreliable access to basic economic opportunities and social services. For their transport needs, they rely on motorized and non-motorized means of transport.

Rural poverty in developing countries is attributable, in part, to the absence of road access over larger areas (Hoyle, 1998). Poverty and accessibility are correlated to a certain extent and also poverty and ill-health prevalent among rural population in developing countries is compounded by poor physical access (Porter, 2002). The percentage of people below the poverty line in Nepal is approximately 42 percent and in unconnected areas is as high as 70 percent (Lebo and Schelling (2001).

Rural transport consists of three elements: (a) location and quality of facilities, (b) transport infrastructure, and (c) transport services. Access problems can be solved only when all three elements of rural transport systems are available.

Providing basic access to markets for local products and social services for the people who live in rural areas is one of the most significant challenges in developing countries. Consistent with a basic-needs focus, the basic-access approach gives priority to the provision of reliable, all-season access, to as much population as possible (Lebo and Schelling, 2001). Lack of reasonably reliable and economic means of personal and goods transport in rural areas is thought to be major constraint to rural development (Beenhakker, 1987). Transport infrastructure and transport means play a vital role in attaining the basic needs of rural population (Vasconsellos, 1997).

In developing countries, the provision of basic access is limited by the availability of resources. In following cases travel to service centers via the existing trail networks would be the only alternative.

- Where no road network is available
- Where road network is available but no transport services are available and
- Where motorized access is not affordable

RTI includes the intra- and near-village transport network, as well as the infrastructure that provides access to higher levels of the road network (Lebo and Schelling, 2001).The RTI network is the lowest level of transport system that connects the rural population to their farms, local markets, and social services such as schools and health care service centers in a close proximity to the settlement villages.

The RTI network in developing countries consists of an estimated 5-6 million kilometers of rural roads, tracks and paths and pedestrian trails (Lebo and Schelling, 2001). The majorities of trips that take place over RTI constitute short distances (less than five kilometers) and are made by non-motorized means, including walking, animals, bicycle, and porterage (Lebo and Schelling, 2001).

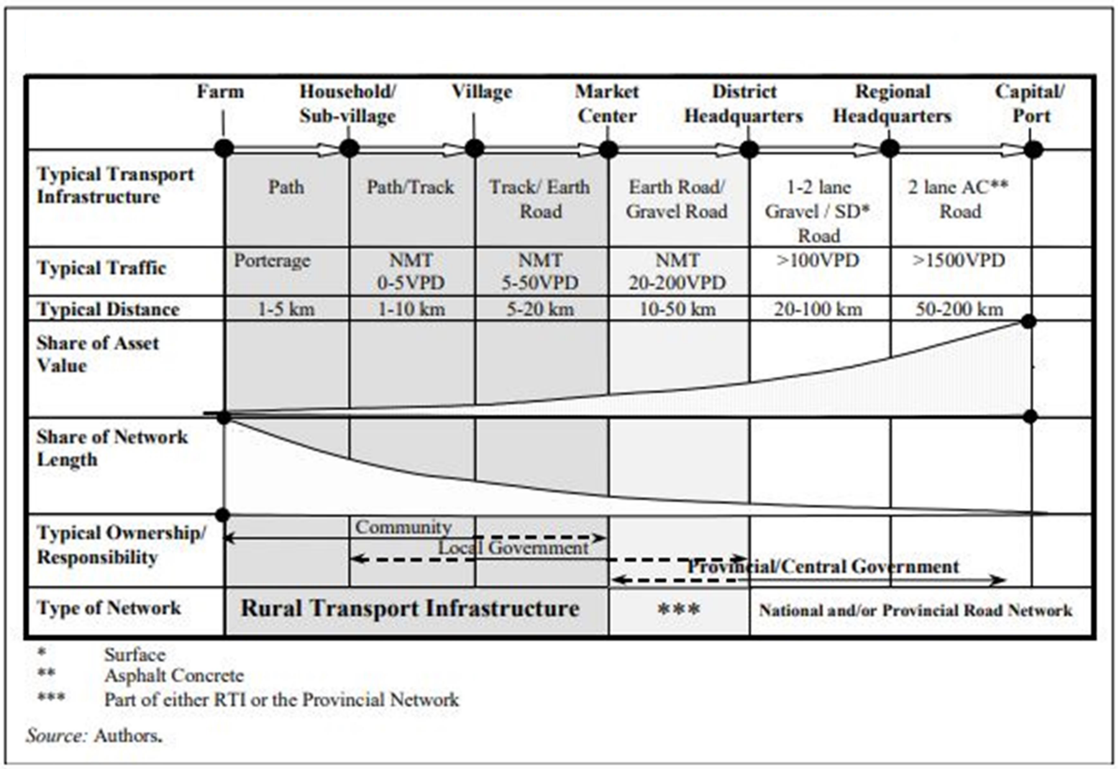


Figure 1-1: Farm to Market Transport Chain and Transport Infrastructure (Jerry Lebo, 2001)

Worldwide experience from past rural development programs and policies suggests that improving the poverty impact of RTI interventions requires an emphasis on reliable, cost-effective access to as much of the rural population as possible, rather than high access standards for a few (World Bank, 2001).

1.3. Accessibility to Social Service Centers in Rural Areas

1.3.1. Transport Services

The purpose of transport is to provide accessibility, or the ability to make a journey for a specific purpose (Hoyle et al., 1998). Many developing countries have been struggling to find the resources to provide a basic level of access, especially in rural areas. It is normally assumed that access to a basic minimum range of facilities is economically and socially necessary for the pursuit of a normal way of life (Hoyle et al., 1998). The rural problem, therefore, is the lack of accessibility (Hoyle et al., 1998). Accessibility decisions are critically important to development "because a large proportion of the population in developing countries is rural and their transport and communication systems are poorly developed and costly to use" (Rushton, 1984).

Essential social services are harder to reach from rural areas than in towns and cities (Haynes, 2003). Rural people might be doubly disadvantaged because they live far from the service centers and do not have access to reliable transport infrastructure and services (Haynes et al., 2003). A country's ability to maximize its economic potential is closely linked to the efficiency of its transport system.

Transport improvements also help to reduce poverty through improving the quality and security of access to employment, markets and social services (Gannon, 2001). Almost half of the world's population lives in rural areas where lack of proper transport is a constraint for development and such condition will continue for many decades to come (Ravallion, 2000). The predominant means of transport in the rural areas of developing countries is walking (Barwell, 1985) . Barwell et al. (1985) and (Gannon, 2001) comment that people make their journeys with loads carried on their head (India, Sub-Saharan Africa), on the back (Korea, Nepal, Sub-Saharan Africa) and shoulder (Malaysia, Nepal). People are used to waking days, sometimes weeks carrying essential things to help them in their day-to-day survival. Social services constitute an integral part of the infrastructure required for development in rural areas. The spatial distribution of social services depends basically on the location of human settlements in an area and, more importantly on the level of accessibility. Social service delivery in rural areas is more effective if there is trouble-free accessibility.

1.3.2. Accessibility to Service Centers

Accessibility is a fundamental topic of transport Engineering. The history of accessibility is typically expressed as the history of the development of particular measures, such as topological, cumulative opportunity, population potential or space-time (Kwan, 2003); (Horner, 2004) as cited in Weber, 2006). (Weber, 2006) Argues that the geographical concept of accessibility is based on the following; there must be some spatial separation of origins and destinations, such as between population settlements and service centers, which people have a need or desire to move between. There must also be an impedance or restriction on movement which can be travel distance, travel time or cost of travel.

The concept of accessibility is used in many contexts and in many different ways; for instance as a goal in transportation policy, as a means in rural development policy, as an indicator of rural deprivation, and as a variable in location analysis (Mosely, 1979). Accessibility can be defined as the ease or difficulty of reaching or using a facility or service, and therefore, concerns both the mobility of people and the availability of services (IRAP, 2005; (Barwell, 1996)). Accessibility can also measure the relative opportunity for interaction or contact with facilities or services (Nicholls, 2001). Barwell et al. (1996) from their studies note that the level of physical accessibility is dependent on two factors: a) the level of mobility; and b) the siting and quality of facilities. (Odoki, 2001) defined accessibility as a function of the mobility of the individual and the spatial location of activity opportunities. The siting and quality of facilities affects the distances and routes between the places of residence or production and the facilities that people make a decision to use (Barwell et al., 1996). Accessibility of people in general can be improved either by enhancing mobility through the development and provision of transport infrastructure and services or by locating facilities and services closer to rural communities (Barwell, 1996). Locating facilities close to settlements and improved management of accessibility to these services are the key elements of location allocation and resource management (IRAP, 2005). The definition of accessibility can be based on the theories of travel behavior. The amount and nature of movement of people depends on the amount and nature of activities. Measures of accessibility consist of two parts: a transportation element (resistance or impedance) and an activity (motivation or attraction) element. The transportation element reflects the ease of travel between the origin and destination points determined by the character and quality of service provided by the transportation system and measured by travel distance, time or cost involved for the activity. The activity element reflects the spatial distribution of activities or attractiveness of a particular location or trip destination (Handy, 1997).

Handy (and Niemeier (1997)) define accessibility as spatial distribution of potential destinations, the ease of reaching each destination, and the magnitude, quality and character of the activities available there. The parameters of accessibility as the 'rural challenge' were set out by Moseley (1979) who viewed accessibility as the degree to which someone or something is 'get-at-able'. Farrington define accessibility to be the ability of people to reach and engage in opportunities and activities related to mobility and transport use (Farrington, 2005). Reach implies spatial separation and therefore is related to mobility and transport use. Viewed as opportunities, accessibility is concerned with the opportunities that an individual or community at a given location possesses to take part in a particular activity or set of activities (Jones, 1981). Bryceson define accessibility as physical proximity or the ability and ease of reaching various destinations or places offering opportunities for a desired activity (Bryceson, 2003). Hansen (1959) characterizes accessibility as the potential for interaction.

In planning, accessibility has been used for locating facilities such as schools, health care service centers, administrative service centers, recreation and religious centers, and transport infrastructure and services. Accessibility to economic, recreational, service and social opportunities within a region is an important component of the quality of life within the region (Wachs, 1972). It is also considered an element of the quality of life which influences public policies related to the development of public transportation and communication systems, and location of economic and public services (Wachs and Kumagai, 1972). More importantly, the provision of some form of access is vital for the mobility of people and goods and, in turn, for the development of the economy (Barwell et al., 1985). Levels of accessibility vary by density of population, patterns of settlements and service provision, and level of income among other things. In addition, the levels of accessibility to social services vary between societies and also depend on the geographic location of the settlements, topography of the landscape and availability of transport services (Farrington et al., 2005). Accessibility is determined both by the patterns of land use planning and by the nature of transportation facilities (Handy and Niemeier, 1997).

The transport situation especially in rural areas, generally, can be characterized as ((Gannon, 2001); (Barwell, 1985)):

a) Rural communities are isolated for extended periods as they lack reliable all-season road access. Operations of motorized vehicles are rare and often limited to government agencies and also to non-governmental development agencies.

b) Most trips are short, frequent, time- and effort consuming, and linked to subsistence needs such as collecting water and fuel, crop production, harvesting and processing, etc.

c) Less frequent and longer distance trips are made for visiting hospitals or health service centers, marketing produce, social purposes, etc. Trips for social and welfare activities are a significant proportion of the longer trips made outside the communities. The siting of essential social services thus influences the nature of rural transport requirements.

d) Rural people do not own and rarely can secure access to motorized transport services. They are reliant on walking, and non-motorized transport especially head, shoulder and back loading, and predominantly animals (mules, cattle, horses, etc.) for carrying loads.

As the local level centers are administrative service centers to people since it provide many service to people directly at ward level and municipality level (Rural municipality and Municipality). The center was decided on ad-hoc basis resulted lack of equitable access. This study focuses on Nepal, a developing country with serious rural accessibility challenges and a very challenging physical environment. This thesis reviews the existing accessibility patterns in rural areas of Nepal and proposes and tests various approaches for optimizing the location of public facility centers (administrative centers, School and Health Centers) to equitable access from all the population centers.

1.4. Transport Sector and Accessibility to Service Center in Nepal

1.4.1. Transport and Accessibility

The World Bank (2001) emphasizes that in order to complement poverty reduction strategies, development of rural transport infrastructure and services must be an integral part of rural development interventions and should focus on the mobility and basic access needs of rural communities. As the majority of the population lives in the rural areas and is lacking road transport access, providing road access and uninterrupted linkage to economic and social service centers by constructing roads and bridges is considered a development priority program in Nepal. Personal mobility has been considerably stimulated by the availability of public transport services, particularly as an alternative to the porterage of head loads (Howe, 1984). Few regular transport services operate away from all-weather road networks. However, many people live remote from such networks and hence lack access to motorized transport services.

Until the late 1950's, pedestrian foot-trails and mule tracks were the only means of transport and communication throughout the country. Since then, considerable efforts have been made to link important geographical areas and socio-economic services of the country with transport services. Strategic road network 12,898.20 km of has been constructed (Department of Roads, Nepal (2015/2016)). Similarly Local roads network consists of 57,632 km as per DoLIDAR (2015/16).

Most of these roads are concentrated in the southern part (plain terrain) of the country and in some mid-hill districts.

1.4.2. Service Delivery in Rural Areas

In Asian region, approximately 475 million, live and work in rural areas (Asian Development Bank [ADB], 2011). Majorities of the rural households have little or no access to primary health care, education, safe drinking water, sanitation or other basic services (International Fund for Agricultural Development [IFAD], 2015).Data shows that 80 percent of the total population resides in rural areas are living with poor networking of infrastructure and public service delivery system (Central Bureau of Statistics [CBS], 2011).There are more than 7 million Nepalese people living below the poverty line (National Planning commission [NPC], 2015).Nepalese constitution-2015 implemented 744 local levels and redefined 22 power/jurisdictions.

Service delivery in rural areas is more costly than in urban areas - a key challenge for governments at all levels (Ser). Rural regions face a particular challenge in the form of relatively high costs of service delivery due following regions:

- Lower density populations,
- Larger distances that have to be travelled by service users and service providers,
- Small numbers of people in any location that preclude economies of scale.

The following institutions are responsible for the delivery of public services.

Table 1-1: Rural Service Providers in Nepal

SN	Description of services	Institution
1	Irrigation	Irrigation Development office, Municipalities
2	Water Supply	Water Supply Division office, Water supply users, Local Level Municipalities
3	Electricity	Electricity Distribution office, Enhancement from Municipalities
4	Road	DoR, DoLI, Infrastructure Development office under province, Municipalities
5	Communication (mobile network)	Nepal Telecom, Ncell
6	Health	Hospitals and Health Post

SN	Description of services	Institution
7	Education	Schools

1.4.3. Problem Statement

The problem of service facility location has been researched widely all over the world. The study on the location of service facilities is necessary because location of service facility is normally designed from the perspective of service provider while analysis based on customer demand is imperfect.

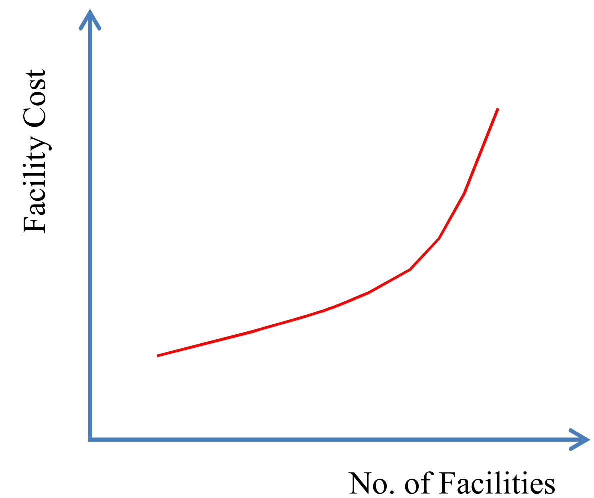


Figure 1-2: Relationship between Number of Facilities and Facility Costs (Meindl, 2013)

Figure 1-2 shows the relationship between facility cost and number of facilities. In this figure, facility cost is getting high along with the number of facilities increases. For controlling investment on facility cost and overhead cost for the extra employee's remuneration, the service providers are obviously willing to deliver services to the maximum number of demands with minimum number of facilities as possible.

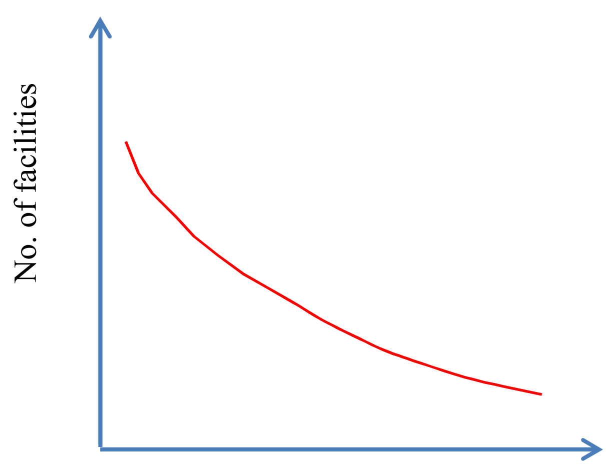


Figure 1-3: Relationship between no. of facilities and response time

The relationship between the number of facilities and desired response time is shown in figure 2 above, and the desired response time is increasing along with the number of facilities decreases. Most of the customers today do not have that much time and/or patience to travel a long distance or wait in line because they prefer to be served immediately and appropriately (Yu, 2014).Due to different objectives of service providers and customers , a clash arises. On the one hand, the service network of a service providers contains as many of facilities close to their customer improves accessibility in terms of customer demands, but on the other hand investment and operating cost also increase. In contrast, a limited number of facilities in a service provider's service network will decrease the cost under the premise of sacrificing response time and the customer satisfaction.

The point is to determine a proper quantity and locations of service facilities, so that the existing performance of service network could be improved.

Recently, Nepal has been structurally changed to federal state having three layers of structure viz. Federal, State and Local level as per the constitution promulgated in 2072 B.S. After the recommendation of the Local Level Restructuring Commission Government of Nepal had approved 744 local levels and published in the Nepal gazette in 2073 B.S. After a one year in 2074 B.S. the government of Nepal has made 753 Local levels. This implies that the restructuring was done without proper technical and social consideration which may lead to raise many restructuring issues of local level near future. The technical committee at the district level had the following criteria for fixation of the number of wards in a rural municipality (GoN, 2073) .

a) Population
b) Administrative easiness
c) Community togetherness and cohesiveness
d) Natural resources
e) Non splitting of ward of vdc

In above criteria, except population others were subjective in nature. The technical committee focused on population for the fixation of the ward. In hilly region where population is less and also scattered along the large geography are relatively disadvantaged from administrative easiness during the restructuring process.

The ward number limit of the rural municipality is 5-21 as per the "determination of number and territory of ward of Municipality and Rural Municipality" Act 2073 (GoN, 2073 B.S.).The criteria set in the above act for change the number of ward and territory of the concerned rural municipality is as follows.

a) Population and Population distribution
b) Geographical Compatibility
c) Language, culture and social factor
d) Delivery of service and ease
e) Physical infrastructure status

So the administrative centers (ward centers) are allowed adding legally. This study focuses on how many numbers are the optimal ward centers in Tribeni Rural Municipality, Rolpa as case study.

1.5. Research Objectives

a) To find the Palika center from distance and population consideration.
b) To analyse the number of ward centers versus population distance.

1.6. Assumptions of the study

The population of the ward is centralized at the geometric center calculated from rural transport network. At ward level, the people go to service center by foot. The settlement/ villages are the smallest units for the service delivery and treated as node.

1.7. Limitations of the study

Only length parameter is considered. No other attributes of transport network (Road and Trail) is considered.

1.8. Significance of the Study

Location of the Rural Municipality center from technical consideration is found out by manual method using Flyod warshall algorithm and Microsoft excel. Since size of matrix is large, the number of constraints and variables are also too large. In this case data analysis can't solve as number of ward centers are more than one. Similarly, in Tribeni Rural Municipality, there are altogether seven ward centers. After this study the optimal number of ward and their centers are found. It will be benefit for the government policy makers to fix the rational way of locating ward centers of the Municipality.

1.9. Organization of the Thesis

The thesis is organized in four chapters. Chapter one introduces about facility location and accessibility issues and transportation in developing countries. This chapter further discusses the important role and contribution of foot trail in providing access to social services particularly in the rural areas in Nepal.

Chapter Two establishes the research context and provides a literature review relevant to the development of this thesis. It reviews some discrete location models (Set covering, Maximum covering location problem and p-median model) relevant to transportation planning and practices for solving facility location problem. It also describes about the GIS applications related to planning of RTI. It provides a brief historical overview of the development and evolution of the RTI knowledge and technology in general, and the RTI practices in Nepal, in particular.

Chapter Three describes the study area, data sources and research methods. It provides background information about the study area, location. It introduces the brief description of the Rolpa district, socioeconomic development indicators, development of transport infrastructure and accessibility to social services.

Chapter Four presents the results and analysis for the research objectives using ArcGIS applications. Outputs of the results from the existing accessibility patterns and analysis are presented first considering technical criteria and socio-economic criteria. This is followed by an analysis of the service index of each village and projected in each ward level of the study area.

Finally, Chapter Five discusses and summarizes the findings of the research. It discusses the advantages of using GIS applications to enhance and facilitate efficient decision making in planning of public facility location with technical and socio-economic consideration. It also suggests areas for future research. The chapter ends with implementation aspects of the research outcomes and possible problems (implications) that need to be addressed and considered in implementation. The Appendices contain database documentations, ArcGIS-derived maps, and diagrams that complement the outcomes of the results and analysis.

Chapter 2 LITERATURE REVIEW

2.1. Facility Location Problem

The optimal location problem refers to build one or several optimal facilities to provide best service for existing facilities. A set of facilities here are generalized: it can be facilities that provide services or facilities need to be served.

Facility location problem can be divided into two aspects in terms of network location: continuous location problem and discrete location problem (Daskin, 2011). The objective of continuous location problem is to “generate” nodes for locating new facilities relative to a set of existing facilities situated at given points in the space (Brimberg, 2008) . Continuous location problem is difficult to find the solution and it is also called also absolute location problem. Discrete location problem is also known as the vertex location problem where facility candidate points are identified beforehand as nodes on a graph. Based on the above explanation of two different types of facility location problems, this paper will focus on discrete location problem.

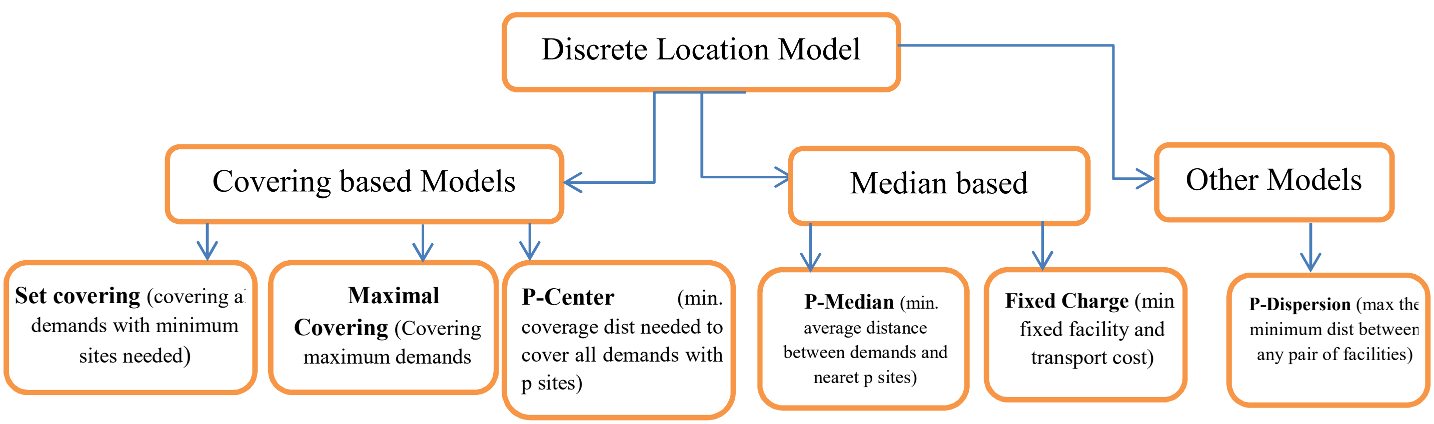


Figure 2-1: (Daskin, 2008) Three broad aspects of discrete location models

2.1.1. Set covering location problem

(Toregas, 1971) et al. introduced the set covering location model with the propose of finding the minimum number (or cost) of facilities and their locations, so that each node-supplier must serve the facility with the specified maximum response time or distance, radius.

For any emergency location in the event of an accident, the time or distance from the nearest emergency service facility to the emergency point must be stipulated, that is the time or distance must less than or equal to a specified value for reaching it in time. This model is used to determine the location of emergency service facilities with minimized number of facilities for improving availability for customers.

2.1.2. Maximal covering location problem

The precondition of finding minimum number of facilities and their locations through set covering location method is that all of demand points must be covered. In another word, facility location designers are no need to worry about the construction investment too much. However, a budget does exist for the most of cases (Current, 2002). When the decision maker does not have enough resources to meet all needs, a workaround is he or she needs. For improving the efficiency of facility usage, decision maker must locate a fixed number of facilities and the specified maximum response time or desired service distance in such a way, as few people as possible lie outside the line (Rahman, 2000).

2.1.3. P-median problem

P-median the classic is mathematical model. According to Mark S. DASKIN's theory, the p-median is under the branch of median-based models in discrete location models. Thus, the goal of p-median mathematical model is to minimize the weighted demand average distance between a demand site and facility (Current, 2002) . P-median model was proposed by S. L. HAKIMI for finding optimum location of switching center in communication network (Hakimi, 1965) and a police station in a highway system (Hakimi, 1964). The mathematical model of p-median location problem can be formulated as follows:

Minimize $\sum_{i,j=1}^{n} hi * dij * Xij$

Subject to $\sum_{j=1}^{n} \mathrm{Xjj} = \mathrm{P}$

$\sum_{j=1}^{n} \mathrm{Xij} = 1$ For all i

$X_{ij} \leq X_{jj}$ for all i,j

X_{jj} =1 if point j is a median, otherwise 0

X_{ij} =1 if a non-median i is attached with to a median j, otherwise 0

2.2. GIS Applications in Transportation Planning

2.2.1. GIS Application

The manipulation and analysis of spatial data are tasks frequently encountered by planners. The processes involved manual handling of spatial data stored in the form of map sheets are difficult and time consuming. The computer- based, GIS has developed as the primary technology for spatial data handling. Planners use GIS as an analytical tool for solving specific problems, most often on a project related basis. GIS applications are being applied increasingly to a variety of pressing human and natural problems including infrastructure planning, resource management, and public service provision among others. GIS applications are becoming more popular amongst professional planners, mangers and decision makers (Yeh, 1990). GIS comprises a software to analyse out well defined functions (GIS software); digital representation of various aspects of geographic world in the form of datasets (GIS data); a computer hardware platform (computer); a community of people who use these tools for various purposes (GIS user community, institutional arrangement); and the activity of using a GIS to solve problems.

The key skill involved in GIS applications is the management of spatial and non-spatial attribute data and the linkage between them (Wang, 2006). An underlying principle of GIS is the ability to overlay different kinds of information for a specified geographic area, such as transportation networks, distribution of facilities and demographic data, so that the relationship between them can be assessed (Nicholls, 2001). The advent of GIS has greatly facilitated the storage, updating, retrieval and display of spatial data that were previously maintained on paper (Klosterman, 1995). GIS enables users to assemble, store, manipulate, visualize and display geographically referenced data more effectively. GIS uses computerized mapping and information system to combine spatial data with associated attribute data to facilitate spatial data analysis for improved decision making.

2.2.2. GIS in Accessibility Planning

An important concept in spatial analysis is accessibility. Accessibility can be quantified by measuring of the nearness to opportunities. Accessibility refers to the relative ease by which the locations of activities such as social services, work and market centers can be reached from a given location (Luo, 2003). The simplest measures of accessibility are the topological measures which reflect the spatial barrier between populations and service centers.

2.3. Public Facility Location

2.3.1. Rural public facility location in hilly regions of Nepal

Since public facility location is the common interest of the public, scope of public facilities locations such as schools or hospitals are increasing day by day. (Antunes, 2007) has make the clear demarcation between private and public facility; "profit maximization and capture of large market shares from the competitor" is main features of the private facility and " social cost minimization, universality of services, efficiency and equity are the goal of the public facility". Schools, hospitals, police units are the examples of the public facilities. They developed a discrete hierarchical location model for public facility planning i.e. school, considering several levels of demand and several types of facilities. This model is an extension of the well-known p-median model. It applied to facility location problems where the objective was to maximize the accessibility of users to facilities and minimization of the cost at the same time. Leonardi 1980 approached two types of flow system i.e. Delivery system and user attracting system. In delivery system, transport always takes place from facility location to demand location. Delivery types of flow system are useful in the study of emergency case (ambulance) and private facility location study. In this study the user attracting system of flow system is more rational since the population node who seeks the services at the village centers and population flows from demand location to the facility.

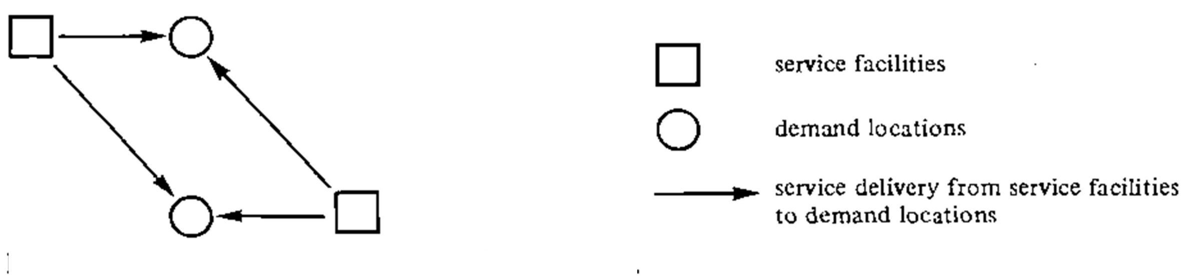


Figure 2-2: A Typical Delivery-System Flow Pattern (Leonardi, 1980)

Similarly in user attracting system, transport takes place from Demand location to Service facilities. Schools, Health centers are the examples of user attracting system. it is the appropriate model for most meaningful urban service systems.

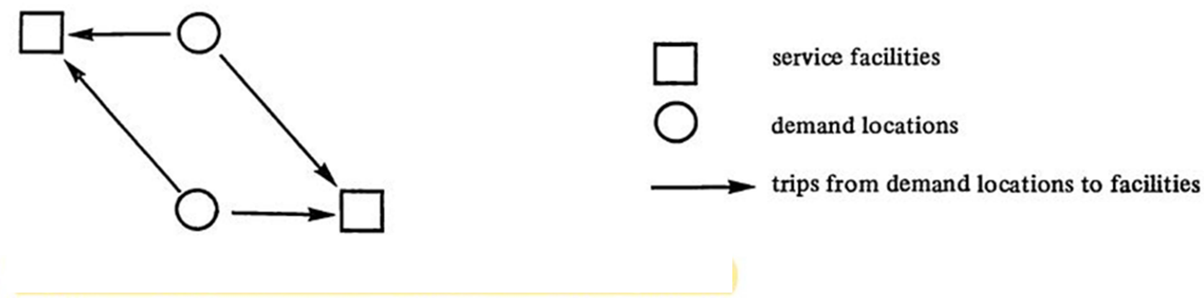


Figure 2-3: A typical user-attracting system of flow pattern

Location decisions are taken by government officers or elected leader or both. In the absence of formal analysis the decision may vary from optimal locations (Rahman & smith 1998). In this paper they examined the role of location allocation model in planning health care system and their relevance in developing nation. Central facilities are those facilities to which people must travel to receive the services.

In our case public service facility is the village administrative center(either ward or municipal) and demand location are the population nodes from where people have to go respective administrative center using existing road network. Since the population mapping is not available, so the primary population node is village and the population is supposed to be concentrated at its center. From the cost minimization point of view, the transport distance/time should be minimized but it may neglect the population weightage. So it is proposed to use population weightage in this research work.

Chapter 3 STUDY AREA AND DATA COLLECTION

3.1. Study Area

The study area is Rolpa district. As per the restructuring of district in 2073, rolpa district has 9 rural municipalities and one municipality. The total area of the district is 1879 square kilometer and total population is 224506. Its elevations range from 701m to 3639m.

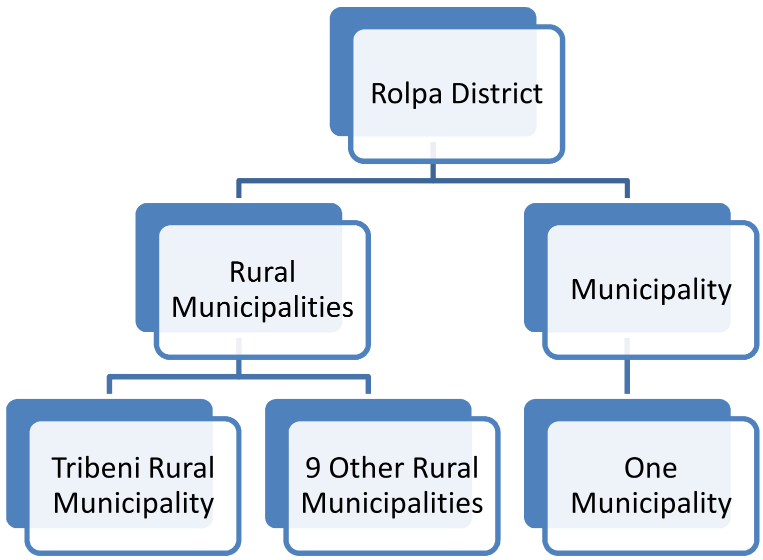


Figure 3-1: Local Level in Rolpa District

3.1.1. Classification of Rural Transport Linkages in Nepal

Rural Road Classification (Nepal Rural Road Standard 2071)

a) District Road (Core Network) – An important road joining a VDC HQ's office or nearest economic center to district headquarters via either neighboring district headquarters or the strategic Road Network.

b) Village Road – Smaller road not falling under district road (Core Network) category are village roads including other village road.

Nepal Rural Road Standard (2055) provides the classification and other general standards for Rural Transport Networks. All rural transport linkages in Nepal are classified into five classes.

These are:

a) Rural Road Class 'A' - District road
b) Rural Road Class 'B' - Village road
c) Rural Road Class 'C' - Main trail
d) Rural Road Class 'D' - Local/village trail
e) Rural Road Class 'E' - Rope way

For this study purpose, Road and Main Trails are taken.

3.1.2. Case Study of Rural Municipality

Tribeni Rural Municipality of Rolpa district was selected for the specific case study representing a typical hilly area in the province no 5.

3.1.3. Transport Status

The road transport system in the Tribeni Rural Municipality is in the preliminary stage of development. Total road network of 258.06 km of road is found in this rural municipality. It has population of 24859 and road density of only **1.258 km** per square kilometer. Similarly the Tribeni Rural Municipality has a main trail network of 231.13 km. In ward level, the trail-based transport system, especially pedestrian foot trails plays an important role in providing basic transport services for the mobility of the people within the ward level. Trails connect settlement villages and social service centers within the ward level. Since no regular motorized vehicle ply in those earthen roads, so for this study both roads and trails are taken into consideration.

Table 3-1: Road Network of Tribeni Rural Municipalitiy

S.N.	Name of Road	Length(km)	Surface Type	Remarks
1	Dahaban-Nigalpani-Koila-Budhgaun-Jugar-Richi (Shahidmarga) Road	42.65	Gravel	
2	Chauke-Dahaban-Nuwagaun-Tribeni-Tila-Gang-Jangdada Road	32.74	Gravel	
3	Gang-Rammi-Dhoreni Road	6.56	Earthen	
4	Tribeni-Jugar Road	8.56	Earthen	
5	Nigalpani-Budhagaun-Lingdung Road	10.33	Earthen	
6	Simpani-Lingdung Road	3.13	Earthen	
7	Nuwagaun (Shahidmarga)-Health Post-Simpani Road	12.07	Earthen	
8	Sakhi-Rampur Road	5	Earthen	
9	Sakhi-Pirale-Bahunpaun Road	4.14	Earthen	
10	Chauke-Hyang Road	6.7	Earthen	
11	Nuwagaun(Shahidmarga)-Hyang- Sirwali-Yari- Kareti	26.22	Earthen	
12	Shahidmarga-Kolbang-Sarange-Shahidmarga	2.69	Earthen	
13	Nerpa-Rijha-Pimakhu-Dahakholagaun-	8.1	Earthen	
14	Wallojugar-Hangjabang-Pedikhola	6.7	Earthen	
15	Wallojugar-Pokharadada Road	1.71	Earthen	

S.N.	Name of Road	Length(km)	Surface Type	Remarks
16	Lingdung-Talloratamata-Daijekholagaun Road	3.43	Earthen	
17	Tallo Ratamata-Ramidada- Koila Road	4.2	Earthen	
18	Tallo Ratamata-Pedikhola Road	3.1	Earthen	
19	Lindung-Jabal-Nerpa(Jugar) Road	4.46	Earthen	
20	Ratamata - Pokharada Road	4.05	Earthen	
21	Jabal-Pokharadada Road	3.47	Earthen	
22	Pokharadada-Dharmakholagaun-Boksithala-Kaulabot Road	3.71	Earthen	
23	Koila_Tikhanbhir Road	5.9	Earthen	
24	Dahaban-Rampur Road	3.82	Earthen	
25	Shahidmarga-UpalloNuwagaun-Bhorja Road	6.36	Earthen	
26	Tribeni-Bahrakunte-Bhaljung-Khangdhara Road	6.44	Earthen	
27	Bhaljung-Dadagaun-Jhunlung Road	4.45	Earthen	
28	Triveni-Bartibang-Maitekatina Road	4.59	Earthen	
29	Jhenam-Chetre Road	1.18	Earthen	
30	Jhenam-Lolekholagaun Road	2.23	Earthen	
31	Jhenam-Dhanidada Road	0.9	Earthen	
32	Jabka- Pungaun Road	6.97	Earthen	
33	Irakhola Road	4.2	Earthen	
34	Irakhola-Chakri Road	3.11	Earthen	
35	ramjali_Link_road	1.26	Earthen	
36	Tila-Ranimala	2.93	Earthen	
	Total Length	**258.06**		

Table 3-2: Trail Network of Tribeni Rural Municipality

S.N.	Name of Trail	Length	Remarks
1	Baphegaun-Luddada Trail	2.387	
2	Bahrakunte-Khangdhara-Ganeulepani Trail	3.524	
3	Bartibang-Pirale Trail	3.238	
4	Boksithala- Ramijyoti Trail	2.696	
5	Chakri-Pungaun Trail	1.424	
6	Chaldhunga-Bakhur Trail	3.993	

S.N.	Name of Trail	Length	Remarks
7	Chhampa-Dumla Trail	4.137	
8	Daphla-Raipal Trail	3.951	
9	Daphla-Sarangee Trail	4.981	
10	Dhairenni-Jaribang-Nerpa Trail	6.602	
11	Dhanidada-Bankul-Shahidmarga Trail	2.287	
12	Dhoreni-Khabanpachha-Darbot Trail	2.543	
13	Gautakura-Lingdung Trail	1.568	
14	Jalekharka- Bhurtigaun Trail	6.663	
15	Jabka-Daruwa Trail	4.351	
16	Jalekharka-Chanbas-Lanbas	2.044	
17	Jalekharka- Sugurpokhari-Chorkholagaun	3.126	
18	Jawal-Kholagaun Trail	5.633	
19	Koila-Simpani Trail	1.676	
20	Lamputlachaur-Chhepa Trail	2.470	
21	Lingdung-Ranagaun Trail	3.074	
22	Lingdung-Tribeni 3- Lingdung Trail	2.233	
23	Maitekatina-Chhampa-Dumla Trail	6.301	
24	Maitekatina-Dumla Trail	3.859	
25	Nanga-Titim-Shahidmarga Trail	3.968	
26	Nuwagaun School-Bahrakunte Trail	1.367	
27	Pokharadada-Pharuli Trail	3.793	
28	Pungaun Trail Loop	1.406	
29	Raibang-Upallo Nuwagaun Trail	1.099	
30	Rammi-Darbot Trail	1.841	
31	Rangbang-Gamalchaur-Kukurgaun Trail	4.743	
32	Ranimala-Kaule-Tila Trail	2.299	
33	Ranimala-Ramijyoti-Oraldhunga Trail	10.443	
34	Simpani-Lamputlachaur Trail	3.323	
35	Simpani-Lichibang Trail	0.811	
36	Sugurpokhari-Bhurtigaun Trail	2.329	
37	Tribeni-Gangkhola-Rammi	4.054	
38	Tribeni-Kawargaun Trail	2.095	
39	Tribeni-Ranagaun-Ranimala	4.726	
40	Upallo Nuwagaun- Bhaljung Trail	1.301	
41	Mid of Baphegaun-Luddada Trail	0.715	
42	Wallojugar-Goitibang Trail	0.390	
43	Wallojugar-Hanjbang Trail	3.091	
44	Ganeulipani-Jhunlung Trail	0.712	
45	Aneri-Kholagaun Trail	1.900	
46	Dhabangdada-Baishakhe Trail	3.284	
47	Bahrakunte-(Tribeni-Chapighat Road) Trail	1.253	

S.N.	Name of Trail	Length	Remarks
48	Kolbang-Birangekholagaun Trail	4.501	
49	Boksithala- Oraldhunga Trail	0.877	
50	Dahakhola-Chorpani Trail	1.075	
51	Bankul-Dwarpani Trail	2.627	
52	Dwarpani Trail	0.443	
53	Nerpa-Ghartidhara Trail	0.784	
54	Simpani-Hwap Trail	1.076	
55	Dadagaun-Jhunlung Trail	1.592	
56	Jiuribang-Siruwali-Kawargaun Trail	2.460	
57	Jaribang-Sherbang Trail	0.678	
58	Jhunlung-Dhaireni Trail	0.374	
59	Karegaun-Resmadada Trail	2.727	
60	Kharsedada-Siruwali Trail	0.577	
61	Jabka-Lampokhara Trail	1.466	
62	Tikhanbhir-(Dahaban-Nigalpani Road) Trail	0.744	
63	Tikhan-Bhir Trail	0.843	
64	Irakholagaun-Pungaun Trail	3.122	
65	Bajibang-Chhapneta Trail	2.707	
66	Dhanidada-Bakul Trail	3.176	
67	Shreekatina-Dhoreni Trail	2.564	
68	Rithangna- Jiuribang Trail	0.579	
69	Sherbang-Jaribang Trail	0.379	
70	Resmadada-Ward office Trail	2.355	
71	Shreekatina-Tukla-Sibandhara Trail	10.960	
72	Koilachaur-Tikhanbhir Trail	4.755	
73	Tila-Thurpalekh Trail	2.117	
74	Rampur-Bhangobari Trail	2.558	
75	Lingdung-Upallochhap Trail	3.575	
76	Pim-Akhu Trail	2.498	
77	Tikhanbhir-Daijekholagaun Trail	2.448	
78	Nerpa-Koiralaneta Trail	1.511	
79	Lapdada-Hanjabang Trail	1.802	
80	Dumla-Bajibang-Jhankri Salla Trail	8.202	
81	Goitibang-Lingdung Trail	1.693	
82	Chetre-Dhanbangdada Trail	3.344	
83	Wallojugar-Link Trail	0.375	
84	Resmadada-Ward office Trail	1.861	
	Total	**231.13**	

Table 3-3: Population Data

Node	Population	Remarks
1	0	
2	0	
3	0	
4	175	
5	0	
6	110	
7	0	
8	0	
9	0	
10	75	
11	110	
12	125	
13	60	
14	100	
15	90	
16	350	
17	95	
18	200	
19	0	
20	0	
21	0	
22	80	
23	90	
24	0	
25	0	
26	125	
27	350	
28	0	
29	175	
30	110	
31	0	
32	0	
33	75	
34	125	
35	0	
36	25	
37	0	
38	0	
39	75	
40	0	
41	0	
42	0	
43	0	
44	0	
45	0	
46	0	
47	300	
48	0	
49	0	
50	125	
51	500	
52	125	
53	0	
54	0	
55	0	
56	0	
57	0	
58	125	
59	0	
60	325	
61	1000	
62	0	
63	0	
64	150	
65	0	
66	0	
67	0	
68	100	
69	0	
70	0	
71	0	
72	0	
73	0	
74	100	
75	0	
76	65	
77	0	
78	0	
79	200	
80	0	
81	0	
82	0	
83	0	
84	185	
85	0	
86	0	
87	435	
88	0	
89	0	
90	360	
91	125	
92	0	
93	125	
94	0	
95	75	
96	175	
97	0	
98	0	
99	75	
100	0	
101	0	
102	1100	
103	0	
104	275	
105	40	
106	150	
107	0	
108	0	
109	0	
110	0	
111	0	
112	225	
113	0	

Node	Population	Remarks
114	260	
115	0	
116	150	
117	0	
118	0	
119	415	
120	0	
121	10	
122	0	
123	300	
124	150	
125	125	
126	175	
127	425	
128	0	
129	375	
130	0	
131	0	
132	125	
133	275	
134	0	
135	0	
136	0	
137	0	
138	0	
139	0	
140	0	
141	100	
142	100	
143	150	
144	0	
145	0	
146	90	
147	220	
148	0	
149	0	
150	0	
151	150	
152	0	
153	0	

Node	Population	Remarks
154	125	
155	0	
156	0	
157	0	
158	0	
159	75	
160	150	
161	0	
162	100	
163	0	
164	100	
165	0	
166	150	
167	50	
168	0	
169	0	
170	0	
171	125	
172	90	
173	275	
174	0	
175	700	
176	0	
177	0	
178	0	
179	0	
180	0	
181	125	
182	100	
183	0	
184	250	
185	160	
186	0	
187	100	
188	40	
189	0	
190	0	
191	0	
192	0	
193	0	

Node	Population	Remarks
194	0	
195	0	
196	0	
197	0	
198	0	
199	0	
200	100	
201	900	
202	100	
203	0	
204	100	
205	0	
206	0	
207	125	
208	0	
209	325	
210	80	
211	150	
212	0	
213	100	
214	0	
215	0	
216	0	
217	0	
218	0	
219	75	
220	0	
221	50	
222	0	
223	0	
224	0	
225	0	
226	40	
226	100	
227	0	
227	0	
228	0	
228	750	
229	100	
229	125	

Node	Population	Remarks
230	0	
230	0	
231	750	
231	40	
232	125	
232	0	
233	0	
233	0	
234	40	
234	0	
235	0	
235	100	
236	0	
236	0	
237	100	
237	0	
238	0	
238	0	
239	750	
239	60	
240	125	
240	160	
241	0	
241	150	
242	40	
242	200	
243	0	
243	50	
244	0	
244	150	
245	100	
245	0	
246	0	
246	0	
247	750	
247	0	
248	125	
248	0	
249	0	
249	50	

Node	Population	Remarks
250	40	
250	140	
251	0	
251	0	
252	0	
252	0	
253	100	
253	0	
254	0	
254	0	
255	750	
255	35	
256	125	
256	150	
257	0	
257	125	
258	40	
258	75	
259	0	
259	340	
260	0	
260	0	
261	75	
262	280	
263	100	
264	20	
265	0	
266	75	
267	0	
268	125	
269	0	
270	0	
271	100	
272	0	
273	100	
274	0	
275	425	
276	50	
277	0	
278	50	

Node	Population	Remarks
279	0	
280	0	
281	130	
282	0	
283	0	
284	0	
285	50	
286	350	
287	325	
288	100	
289	75	
290	0	
291	160	
292	0	
293	50	
294	144	
295	0	
296	60	
297	0	
298	0	
299	350	
300	100	
301	0	
302	75	
303	165	
304	190	
305	400	
306	105	
307	0	
308	0	
309	85	
310	150	

Chapter 4 RESEARCH METHODOLOGY AND DATA ANALYSIS

4.1. Research Design

The ward centers are required to the village/settlement for many services. The major issue for this research is how to identify the demand point and the ward centers into the reliable data to analysis. The population and road/ trail network distribution throughout the municipality is not uniform. Hence, the demand is not uniform. To simplify this problem the villages/settlements with assigned respective populations are taken as a demand points.

4.2. Methodology of this Research

Following steps has been followed while doing this research.

4.2.1. Literature Review

Various literatures related to the facilities location is studied as already illustrated in the previous Chapter of Literature Review. Previous research in this field is collected and studied. Similarly The District Transport Master Plan (DTMP) of Rolpa District is studied for understanding the geographical, socio-economic and other aspects of Tribeni Rural Municipality.

The methodology utilizes a GIS to prepare and analyze the spatial and attribute database of the road and trail network of rural municipality. ESRI ArcGIS 10.2, QGIS 1.8.0 used to create, acquire, edit and manage spatial and attribute data. Python 3.6 is used to analyze the relationship between numbers of ward centers versus population distance.

GIS Database of trail network is obtained from Department of Survey and Road network from the District Transport Master Plan of Rolpa 2013. Similarly Population at settlement level from the village profile of the Tribeni Rural Municipality
Since the DTMP of Rolpa district was prepared in 2013 AD. Many Road network are added since then. Above Road Network data are further updated by using hand held GPS. Remaining roads are traced by Google Earth and processed to get the required shape file. Similarly trails are directly loaded from Database from Department of survey. Village Nodes are tracked from the Google earth.

In first part of the study, the ward centers are located considering all networks (road and trail) using Floyd-Warshall. Then only road networks are taken to find the municipality center and population of each ward are loaded.

In second part of the study is to find out the optimal number of ward centers so that village get easy access to the ward centers. The model used in this study is p-median model.

4.2.2. Data Collection

Various data and information related to the research are collected. Some of the data are collected by primary and other by the secondary source. The data collected are listed in the Previous Chapter 3 of Data Collection.

4.2.3. Data Analysis

Each settlement is considered the demand point and is assigned here with a specific number starting from 1 to 310 as shown in Table. 3.3. The distance between each node is identified by the available data of DTMP, Google earth and GPS surveying.

Table 4-1: Distance between Nodes

S.N.	From	To	Distance (Km)	Remarks
1	1	2	1.337	
2	2	5	0.842	
3	2	3	1.497	
4	3	7	0.744	
5	3	8	2.883	
6	4	7	0.686	
7	4	5	0.908	
8	5	18	2.447	
9	6	14	0.758	
10	7	11	2.533	
11	8	10	0.189	
12	8	9	0.144	
13	9	16	1.441	
14	9	11	0.627	
15	10	24	3.12	
16	10	25	2.856	
17	12	19	2.329	
18	12	15	1.534	
19	13	19	1.22	
20	13	17	0.85	
21	14	21	2.34	
22	15	20	1.072	
23	16	28	2.612	
24	17	35	1.869	

S.N.	From	To	Distance (Km)	Remarks
25	18	21	0.59	
26	19	23	0.384	
27	20	30	2.043	
28	20	29	0.917	
29	21	22	0.261	
30	22	28	0.555	
31	23	31	1.521	
32	24	32	1.719	
33	24	26	1.294	
34	25	47	1.774	
35	25	27	0.307	
36	26	45	2.28	
37	27	42	1.26	
38	28	42	1.543	
39	29	30	2.838	
40	30	31	0.3	
41	31	33	0.577	
42	32	37	1.627	
43	32	54	1.676	
44	33	34	0.731	
45	33	38	1.9	
46	34	40	0.518	
47	35	39	0.876	
48	35	44	1.065	

S.N.	From	To	Distance (Km)	Remarks
49	36	54	0.951	
50	37	43	1.756	
51	37	53	0.628	
52	39	50	1.895	
53	39	40	0.088	
54	40	58	0.946	
55	41	65	2.632	
56	42	49	0.479	
57	43	56	0.38	
58	43	46	0.607	
59	44	50	0.711	
60	44	52	1.223	
61	45	60	1.935	
62	45	48	0.135	
63	46	56	1.068	
64	46	69	1.106	
65	47	48	2.233	
66	47	49	0.113	
67	48	51	0.162	
68	49	59	0.305	
69	49	57	0.171	
70	51	63	0.292	
71	53	72	0.898	
72	53	95	2.315	
73	54	55	0.0498	
74	55	60	0.549	
75	55	64	0.48	
76	56	61	0.369	
77	57	63	0.967	
78	57	62	0.121	
79	58	66	0.556	
80	59	62	0.406	
81	59	65	0.93	
82	61	80	1.423	
83	61	70	1.298	
84	62	89	1.303	
85	64	67	0.28	
86	65	88	1.357	
87	65	75	0.724	
88	66	76	0.457	

S.N.	From	To	Distance (Km)	Remarks
89	66	71	0.376	
90	67	73	3.133	
91	67	84	2.8	
92	67	69	0.224	
93	68	99	2.35	
94	69	82	0.459	
95	70	72	1.079	
96	70	97	3.121	
97	71	78	0.644	
98	71	81	0.535	
99	73	74	0.207	
100	73	77	0.027	
101	74	84	0.841	
102	75	52	2.45	
103	75	78	0.7	
104	76	68	0.985	
105	77	79	0.443	
106	77	63	0.745	
107	79	92	1.387	
108	80	87	0.868	
109	80	85	0.537	
110	82	83	0.159	
111	82	93	0.741	
112	83	86	0.34	
113	83	96	0.542	
114	84	92	0.296	
115	85	97	1.508	
116	85	87	0.341	
117	86	103	1.269	
118	86	87	0.0485	
119	88	98	0.832	
120	89	94	0.147	
121	90	78	1.715	
122	90	98	0.579	
123	91	104	1.899	
124	91	98	2.019	
125	92	100	1.054	
126	93	112	1.648	
127	94	101	0.846	
128	94	102	1.605	

S.N.	From	To	Distance (Km)	Remarks
129	95	107	1.466	
130	95	120	1.578	
131	96	103	0.719	
132	97	107	1.482	
133	98	108	0.632	
134	99	104	1.713	
135	100	114	1.18	
136	100	105	0.717	
137	101	122	1.049	
138	102	108	0.27	
139	103	126	1.214	
140	105	112	1.635	
141	106	110	0.779	
142	107	127	1.635	
143	108	109	0.101	
144	108	106	0.731	
145	109	111	0.168	
146	109	122	1.471	
147	109	116	3.292	
148	111	117	0.784	
149	111	113	0.067	
150	113	119	0.704	
151	114	115	0.0987	
152	115	101	0.989	
153	115	123	0.599	
154	116	118	0.737	
155	118	136	2.497	
156	118	121	0.28	
157	119	129	1.787	
158	120	125	0.443	
159	120	128	1.582	
160	121	124	1.018	
161	122	132	1.093	
162	123	139	1.869	
163	124	135	2.769	
164	125	165	2.793	
165	125	146	2.626	
166	126	130	0.336	
167	127	128	0.375	
168	128	130	4.35	

S.N.	From	To	Distance (Km)	Remarks
169	129	145	1.61	
170	130	131	1.082	
171	131	149	1.431	
172	131	133	1.06	
173	132	140	0.69	
174	133	141	1.932	
175	134	135	0.154	
176	135	142	1.671	
177	136	137	0.435	
178	137	150	1.802	
179	138	137	2.432	
180	138	143	0.159	
181	139	141	0.856	
182	139	140	0.143	
183	140	156	0.727	
184	142	143	0.188	
185	143	147	0.21	
186	144	150	1.766	
187	144	136	1.634	
188	144	145	0.023	
189	145	148	0.108	
190	146	168	1.626	
191	146	164	1.549	
192	147	157	1.324	
193	147	150	1.324	
194	148	152	0.171	
195	148	153	0.375	
196	149	151	0.82	
197	149	158	0.727	
198	151	155	0.634	
199	152	167	1.715	
200	152	153	0.959	
201	153	166	1.216	
202	154	163	0.927	
203	154	155	0.684	
204	155	177	1.671	
205	156	159	0.678	
206	156	162	0.379	
207	158	160	1.66	
208	158	172	0.457	

S.N.	From	To	Distance (Km)	Remarks
209	159	113	3.616	
210	159	182	1.093	
211	160	171	1.292	
212	163	168	0.715	
213	163	173	0.408	
214	164	165	1.105	
215	165	169	0.237	
216	166	186	1.355	
217	167	178	0.39	
218	168	212	2.286	
219	168	188	1.102	
220	169	198	2.053	
221	169	181	0.655	
222	170	186	2.707	
223	170	161	0.843	
224	170	175	0.701	
225	171	174	0.405	
226	172	183	0.501	
227	173	177	0.366	
228	174	189	1.591	
229	174	179	1.041	
230	176	203	1.485	
231	176	184	0.856	
232	176	183	1.533	
233	177	180	0.584	
234	179	185	0.55	
235	180	193	0.89	
236	180	184	0.445	
237	181	197	1.572	
238	182	208	1.892	
239	183	196	0.682	
240	185	189	0.486	
241	186	192	1.678	
242	187	195	0.758	
243	187	192	1.977	
244	188	197	1.311	
245	189	194	0.225	
246	190	222	1.68	
247	190	162	1.427	
248	190	191	0.27	

S.N.	From	To	Distance (Km)	Remarks
249	191	194	0.103	
250	192	201	0.716	
251	193	216	1.758	
252	193	203	1.098	
253	194	202	0.489	
254	195	230	2.559	
255	195	199	1.191	
256	196	200	1.556	
257	196	207	0.689	
258	197	205	0.869	
259	198	206	0.561	
260	198	204	1.187	
261	199	201	0.885	
262	200	202	1.438	
263	200	218	1.597	
264	201	175	5.122	
265	201	215	0.906	
266	203	209	0.291	
267	204	211	0.834	
268	205	225	2.181	
269	205	211	0.328	
270	206	233	1.169	
271	206	213	0.531	
272	207	217	1.198	
273	208	241	3.394	
274	208	210	0.07	
275	209	214	0.412	
276	210	195	1.781	
277	210	230	1.005	
278	212	216	0.658	
279	212	225	1.297	
280	212	224	0.674	
281	213	223	0.543	
282	214	220	0.365	
283	215	219	1.662	
284	215	231	1.299	
285	216	220	0.698	
286	217	218	0.183	
287	218	226	0.419	
288	220	228	0.372	

S.N.	From	To	Distance (Km)	Remarks
289	221	236	0.544	
290	221	223	0.517	
291	222	227	1.252	
292	222	246	1.212	
293	223	234	1.922	
294	224	235	2.107	
295	224	229	0.179	
296	225	234	3.684	
297	226	228	1.366	
298	226	227	0.046	
299	228	237	0.467	
300	229	232	0.888	
301	230	219	2.474	
302	231	240	1.342	
303	232	238	0.316	
304	233	270	6.055	
305	233	236	1	
306	234	250	2.558	
307	235	239	0.812	
308	236	242	0.935	
309	237	238	0.635	
310	237	245	0.934	
311	238	244	1.953	
312	239	257	2.06	
313	240	247	1.478	
314	241	252	1.124	
315	242	254	2.889	
316	243	247	0.977	
317	243	249	1.56	
318	244	267	2.547	
319	245	248	0.197	
320	246	248	0.266	
321	246	227	1.662	
322	247	258	1.977	
323	248	253	0.425	
324	249	273	3.968	
325	250	254	0.893	
326	251	262	2.596	
327	251	245	0.38	
328	251	256	0.484	

S.N.	From	To	Distance (Km)	Remarks
329	252	249	3.914	
330	252	255	0.504	
331	252	253	0.043	
332	253	282	3.093	
333	254	270	4.11	
334	255	273	2.734	
335	256	261	1.392	
336	257	269	2.087	
337	257	263	1.885	
338	258	259	0.492	
339	259	265	2.116	
340	259	260	0.216	
341	259	264	1.06	
342	260	266	1.163	
343	261	278	2.074	
344	262	274	2.219	
345	264	268	1.239	
346	266	275	1.682	
347	267	269	0.677	
348	267	274	1.026	
349	268	260	2.928	
350	270	272	0.647	
351	271	279	2.984	
352	271	268	1.487	
353	271	273	1.503	
354	272	269	4.36	
355	272	263	1.352	
356	274	277	2.657	
357	275	281	1.775	
358	276	277	0.576	
359	277	280	0.841	
360	279	283	0.5	
361	280	287	1.603	
362	280	285	1.128	
363	281	292	1.831	
364	282	284	0.876	
365	282	279	3.553	
366	282	288	0.671	
370	284	285	0.455	
371	286	289	0.888	

S.N.	From	To	Distance (Km)	Remarks
372	286	283	1.342	
373	287	291	0.787	
374	288	294	1.379	
375	290	294	0.189	
375	290	294	0.189	
376	290	293	1.13	
376	290	293	1.13	
377	290	289	0.74	
377	290	289	0.74	
378	290	300	2.563	
379	291	299	2.94	
379	291	299	2.94	
380	293	297	1.413	
380	293	297	1.413	
381	296	298	1.568	
381	296	298	1.568	
382	296	299	0.787	
382	296	299	0.787	

S.N.	From	To	Distance (Km)	Remarks
383	298	301	1.861	
383	298	301	1.861	
384	298	302	2.726	
384	298	302	2.726	
385	299	301	0.321	
385	299	301	0.321	
386	300	302	1.0954	
386	300	302	1.0954	
387	301	304	5.694	
387	301	304	5.694	
388	302	303	1.37	
389	303	306	4.691	
390	304	305	1.64	
391	305	309	2.99	
392	306	310	1.601	
393	307	308	0.51	
394	308	310	2.2	
395	308	309	1.032	

4.2.4. Analysis of the Result considering distance

From the analysis of rural transport network, center of each ward is found using Floyd Warshall algorithm. The following centers were identified.

Table 4-2: Comparison of Ward Center

S.N	Ward No.	Existing Center	New Center from technical consideration	Difference
1	1	12	14	0.321
2	2	44	42	1.725
3	3	27	25	0.592
4	4	7	15	0.618
5	5	6	11	0.335
6	6	12	16	0.518
7	7	25	20	2.469

At rural municipality level the center from technical consideration is found to be at 70 with minimum sum of 965.764km. Similarly existing municipality center of node 30 is with sum of distances 1032.295Km. The saving of travel distance to every node from node 70 is 66.531 Km.

4.2.5. Analysis of the result considering population and distance

Similarly from socio-economic point of view the new center is also coincides in node 70. The person km at node 70 is found to be 190,471.95. Similarly the existing municipality center 30 has a 200,258.000 person km. The saving in person km in new node is found to be 9,786.0 person-km.

4.2.6. Analysis of the result using P-Median Model

Table 4-3: Relatinship between ward centers and population distance

Number of Ward Centers	Population Distance (Person-Km)	Weighted Average Distance (Km)
1	225953.07	9.08
2	165589.7495	6.66
3	140161.4925	5.63
4	121171.7145	4.87
5	108901.3215	4.38
6	98847.3015	3.97
7	91808.3115	3.6
8	85618.1245	3.44
9	80603.707	3.24
10	75748.178	3.04
11	71492.398	2.87
12	67597.318	2.71
13	63946.033	2.57
14	60868.758	2.44
15	57889.9055	2.32
16	55280.2805	2.22
17	52989.2805	2.13
18	50946.8405	2.04
19	49070.5405	1.97

Number of Ward Centers	Population Distance (Person-Km)	Weighted Average Distance (Km)
20	47297.5805	1.90
21	45513.9685	1.83

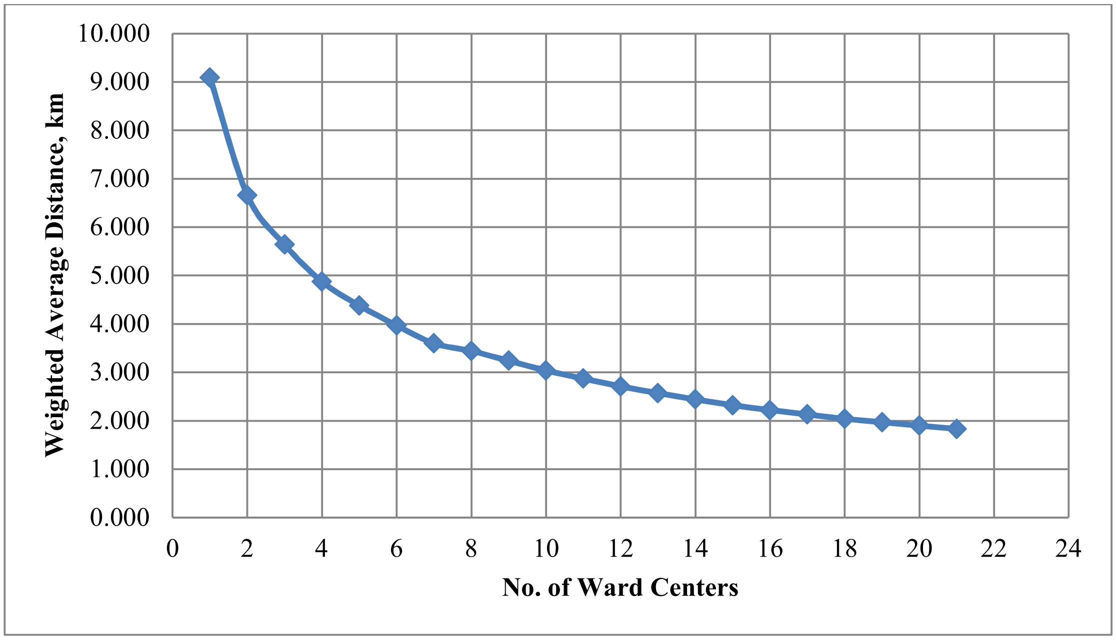


Figure 4-1: Weighted Average Distance Vs No. of Ward centers

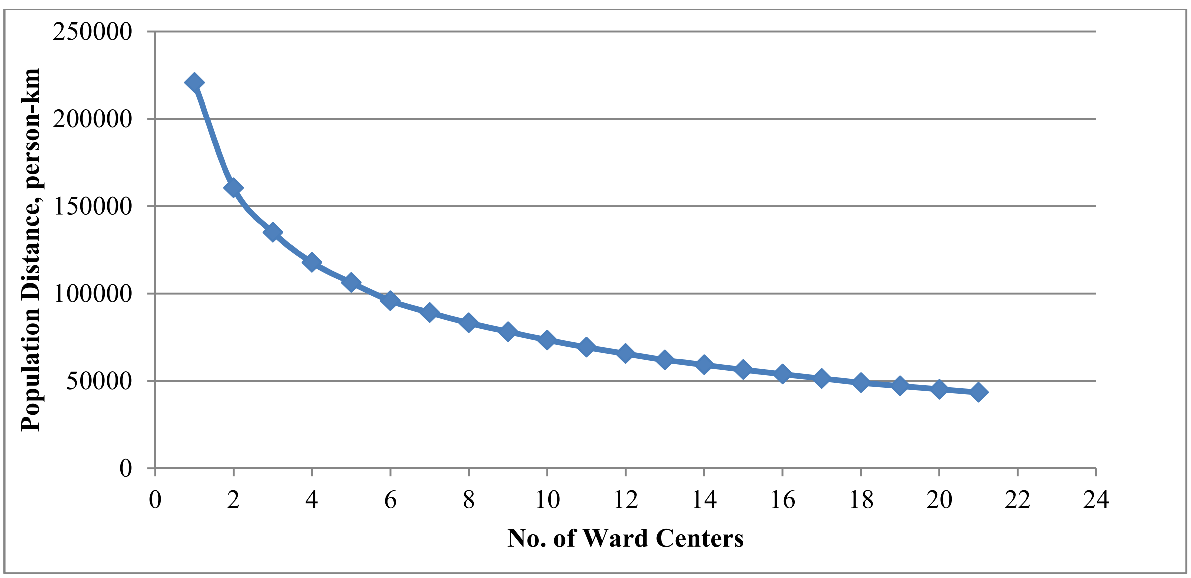


Figure 4-2: Graphical representation of ward centers and population distance

Chapter 5 Conclusion and Recommendation

By using P-Median model we can assign each ward centers so that they can cover every settlement with minimized average weighted distance (walking distance). For any given average weighted distance, the required number of ward centers can be obtained.

From the Graph of average weighted distance versus no. of ward centers it is concluded that with the increase in the number of ward centers, average weighted distance decreases. Similarly, if the average weighted distance is decreased the no. of ward centers is increased. From this we can identify the no. of ward centers required for any given average weighted distance which can connect every settlement.

In Tribeni Rural Municipality currently there are seven ward centers with average weighted distance of 3.6 km. We can vary the ward centers from five to twenty one as per the legal provision of Nepal, average weighted distance decreases from 4.38 km to 1.83 km.

References

Antunes Teixeira. A hierarchical location model for public facility planning [Journal]. - 2007.

Barwell I Transport and the Village. Findings from African Village-Level Travel and Transport Surveys and Related Studies [Journal]. - 1996.

Barwell I. J., Edmonds, G. A., Howe, J. D. G. F. and de Veen, J. Rural Transport in Developing Countries [Journal]. - 1985.

Beenhakker H. Rural Transport Services [Journal]. - [s.l.] : Intermediate Technology Publications, 1987.

Brimberg J., Hansen, P., Mladonovic, N., & Salhi, S. A survey of solution methods for the continuous location allocation problem [Journal]. - 2008.

Bryceson D. F., Maunder, D. A. C., Mbara, T. C., Kibombo, R. and Davis, A. S. C., and Howe, J. D. Sustainable Livelihoods, Mobility and Access Needs [Journal]. - 2003.

Current J., Daskin, M., & Schilling Discrete network location models. Facility location: applications and theory [Journal]. - 2002.

Current J., Daskin, M., & Schilling, D Discrete network location models. Facility location: applications and theory [Journal]. - 2002.

Daskin M. S. Network and discrete location: models, algorithms, and applications [Journal]. - 2011.

Daskin M. S. What you should know about location modeling [Journal]. - [s.l.] : Naval Research Logistics (NRL), 55(4), 283-294., 2008.

Farrington J. and Farrington Rural Accessibility, Social Inclusion and Social Justice Towards conceptualization [Journal]. - 2005.

Gannon C., Gwilliam K., Liu, Z. and Malmberg C. C. Transport: Infrastructure and Services [Journal]. - 2001.

Gannon C., Gwilliam K., Liu, Z. and Malmberg C. C. Transport: Infrastructure and Services [Journal]. - 2001.

GoN [Online] // www.mofald.gov.np. - 2073. - http://mofald.gov.np/sites/default/files/Resources/TOR%20Local%20Technical%20Committee%20-ammended%20-%20final.pdf.

GoN Determination of number and territory of ward of municipality and rural municipality. - [s.l.] : www.rajpatra.dop.gov.np, 2073 B.S..

GoN National Health Policy, Nepal. - 2076.

Hakimi S. L. Optimum distribution of switching centers in a communication network and some related graph theoretic problems [Journal]. - 1965.

Hakimi S. L. Optimum locations of switching centers and the absolute centers and medians of a graph [Journal]. - 1964.

Handy S. L. and Niemeier, D. A. Measuring Accessibility: An Exploration of Issues and Alternatives [Journal]. - 1997.

Haynes R., Lovett, A., Sunnengerg, G. Potential Accessibility, Travel Time and ConsumerChoice: Geographical Variations in General Medical Practice Registrations in Eastern England [Journal]. - 2003.

Horner M. Exploring metropolitan Accessibility and Urban Structure [Journal]. - 2004.

Howe J. and Richards, P. Rural Roads and Poverty Alleviation, Intermediate Technology [Journal]. - 1984.

Hoyle B. and Knowles Modern Transport Geography [Book]. - 1998.

Jerry Lebo Dieter Schelling World Bank Technical Paper no 496 [Journal] // Design and Appraisal of Rural Transport Infrastructure:Ensuring Basic Access for Rural Communities. - 2001.

Jones S. R. Accessibility Measures: A Literature Review, Transport and Road Research [Journal]. - 1981.

Klosterman R. The Appropriateness of Geographic Information Systems for Regional Planning in the Developing World [Journal]. - 1995.

Kwan M., Murray, A. T., O'Kelly, M. E., and Tiefelsdorf, M. Recent Advances in Accessibility Research: Representation, Methodology and Applications [Journal]. - 2003.

Leonardi G A unifying framework for public facility location [Journal]. - 1980.

Luo W. and Wang, F. Measures of Spatial Accessibility to Health Care in a GIS environment:Synthesis and a Case Study in the Chicago Region [Journal]. - 2003.

MAKALE THANDI Service Delivery in South African Rural Municipalities [Journal]. - 2015.

Meindl S. Chopra and P. Supply Chain Management: Strategy, Planning, and Operation [Book]. - 2013.

Mosely M. J. Accessibility: The Rural Challenge [Journal]. - 1979.

Nicholls S. Measuring the Accessibility and Equity of Public Parks: A Case Study using GIS [Journal]. - 2001.

Nicholls S. Measuring the Accessibility and Equity of Public Parks: A Case Study using GIS [Journal]. - 2001.

Odoki J. B., Kerali, H. R. and Santorini, F. An Integrated Model for Quantifying Accessibility Benefits in Developing Countries. [Journal]. - 2001.

Porter G Living in a Walking World: Rural Mobility and Social Equity Issues in Sub-Saharan [Journal]. - 2002.

Rahman S. U., & Smith, D. K. Use of location-allocation models in health service development planning in developing nations [Journal]. - 2000.

Ravallion M. On the Urbanization of the Poverty [Journal]. - 2000.

Rushton G. Use of Location Allocation Models for Improving the Geographical Accessibility [Journal]. - 1984.

Service delivery in rural areas [Online] // www.oecd.org.

Toregas C., Swain, R., ReVelle, C., & Bergman The location of emergency service facilities [Journal]. - 1971.

Vasconsellos E. Rural Transport and Access to Education in Developing Countries: Policy [Journal]. - 1997.

Wachs M. and Kumagai, T. G. Physical Accessibility as a Social Indicator, School of Architecture and Urban Planning [Journal]. - 1972.

Wang F. Quantitative Methods and Applications in GIS [Journal]. - 2006.

Weber A. Theory of the Location of Industries [translated by CJ Friedrich from Weber's 1909 book] [Book]. - 1909.

Weber J. 2006 Reflections on Future of Accessibility [Journal]. - 2006.

www.dolidar.gov.np [Online]. - 2015/16.

www.dor.gov.np [Online]. - 2015/2016.

Yeh A. G. and Batty, M. Applications of Geographic Information Systems in Urban and Regional Planning [Journal]. - 1990.

Yu H., Solvang, W. D., & Yang, J. Improving Accessibility and Efficiency of Service Facility through Location-based Approach: A Case Study at Narvik University College [Journal]. - 2014.

APPENDIX I : PYTHON CODING

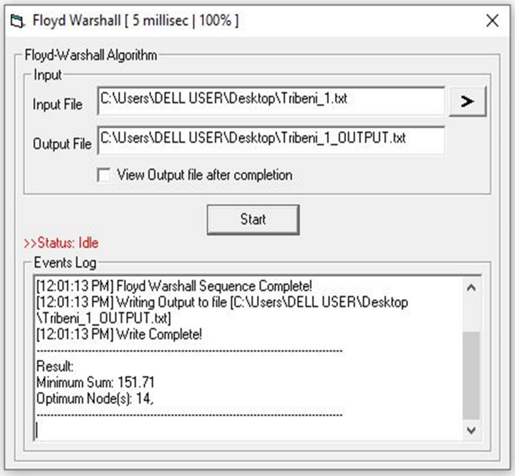
Following Python Coding is used to solve the p-median problem for finding optimal solution of ward centeres in this research. The code is as follows:

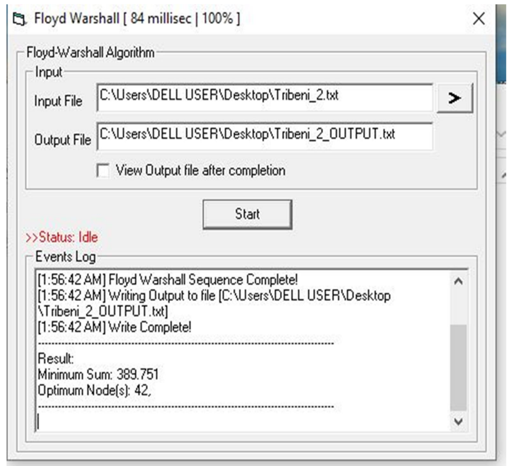
```
from pulp import *

#No of locations

N = 140

#Value of P

p = 1-21

infile = open('inputfile.csv')

D=[]

for j in infile.readlines():

        D.append([float(i) for i in j.split(',')])

H = D.pop(0)

#decision variable

X =  LpVariable.dicts('X_%s_%s', (range(N), range(N)), cat = 'Binary', lowBound = 0, upBound = 1)

prob = LpProblem('P_Median', LpMinimize)

prob += sum(sum(D[i][j] * X[i][j]* H[i] for j in range(N)) for i in range(N))

prob += sum(X[j][j] for j in range(N)) == p

for i in range(N):

        prob += sum(X[i][j] for j in range(N)) == 1

for i in range(N):

        for j in range(N):

                prob += X[i][j] <= X[j][j]

# save the model to a lp fi le

prob.writeLP('p-median.lp')
```

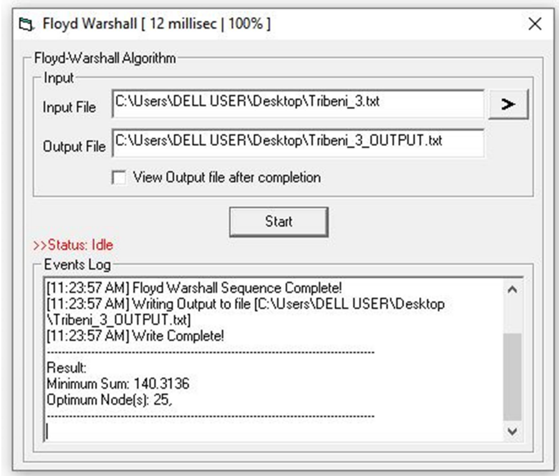
```
# view the model
#print(prob)
# solve the model
prob.solve()
print("Status:",LpStatus[prob.status])
print("Optimal Demand Distance: ",value(prob.objective))
Result = [v.varValue for v in prob.variables()]
res = []
k = 0
for i in range(N):
	#uncomment to print result matrix
	#print(Result[slice(k , k + N  )])
	res.append(Result[slice(k , k + N  )])
	k = k + N
'''
solution = []
for i in range(N):
	for j in range(N):
		if (i == j) and res[i][j] == 1:
			solution.append(i + 1)
#print("The solution locations are")
#print(solution)
#assign = dict.fromkeys(solution, [])
'''
assign = {}
for i in range(N):
	for j in range(N):
```

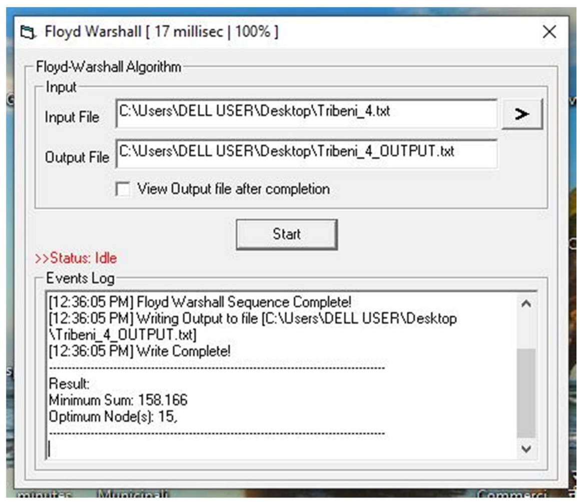
```
                if res[i][j] == 1 and i != j:
                    x = assign.get(j + 1)
                    if(x):
                        x.append(i + 1)
                    else:
                        assign[j + 1] = [i + 1]
print("Solution : ")
print("Optimal Locations")
#print(assign)
for keys in assign.keys():
    print(keys, end = ' ')
print("\n\nAssignment to optimal locations")
for keys in assign.keys():
    print(keys, " : ", assign.get(keys), "\n")
```

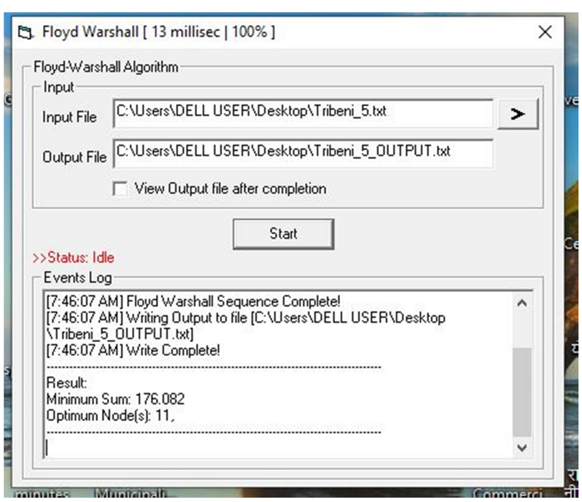
APPENDIX II: FLYOD WARSHAL OUTPUT

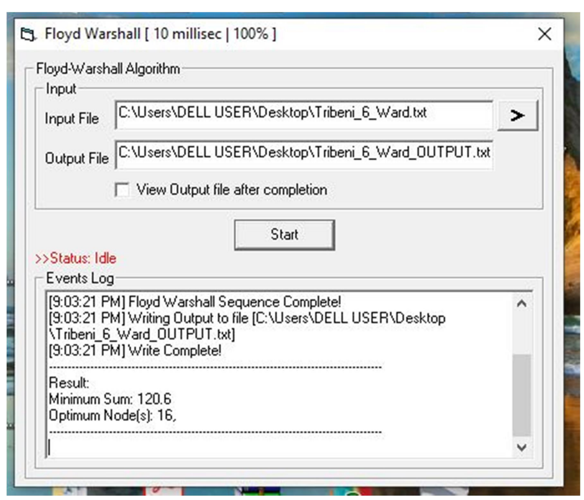


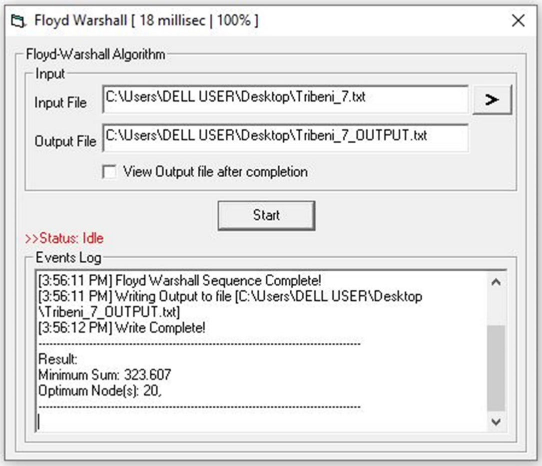


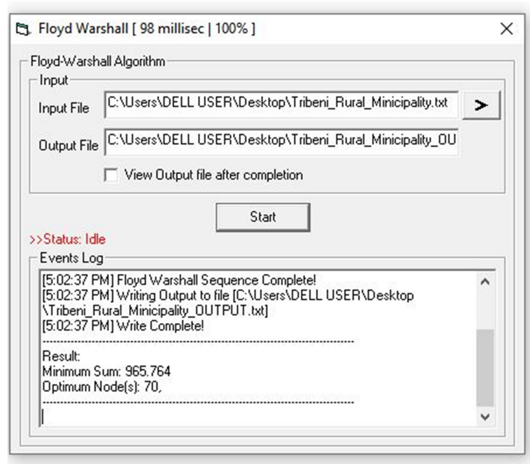









Floyd Warshall [18 millisec | 100%]
Floyd-Warshall Algorithm
Input
Input File
C:\Users\DELL USER\Desktop\Tribeni_7.txt
Output File
C:\Users\DELL USER\Desktop\Tribeni_7_OUTPUT.txt
View Output file after completion
Start
>>Status: Idle
Events Log
[3:56:11 PM] Floyd Warshall Sequence Complete!
[3:56:11 PM] Writing Output to file [C:\Users\DELL USER\Desktop\Tribeni_7_OUTPUT.txt]
[3:56:12 PM] Write Complete!
Result:
Minimum Sum: 323.607
Optimum Node(s): 20,


Floyd Warshall [98 millisec | 100%]
Floyd-Warshall Algorithm
Input
Input File
C:\Users\DELL USER\Desktop\Tribeni_Rural_Minicipality.txt
Output File
C:\Users\DELL USER\Desktop\Tribeni_Rural_Minicipality_OU
View Output file after completion
Start
>>Status: Idle
Events Log
[5:02:37 PM] Floyd Warshall Sequence Complete!
[5:02:37 PM] Writing Output to file [C:\Users\DELL USER\Desktop\Tribeni_Rural_Minicipality_OUTPUT.txt]
[5:02:37 PM] Write Complete!
Result:
Minimum Sum: 965.764
Optimum Node(s): 70,