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A geospatial approach for assessing and modeling spatial accessibility of the primary health centers in the tribal talukas of the Vadodara district

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ABSTRACT

Good health is a prerequisite for global livability of man, and it is a critical component of universal needs, hence a need for equitable distribution of health facilities is a factor for sustaining the population. Essentially, the challenge in many countries is to reach the whole population with adequate health care services and to ensure their utilization. Many peripheral Primary Health Care (PHC) facilities are under used, because of the poor services they provide, lack of access, and willingness. The present study emphasizes on the role of geospatial technique for assessing the spatial pattern of primary health care facilities as well as provides frame work for planning sustainable health care facilities in tribal Talukas of Vadodara district. The objectives are fulfilled by application of GIS and related spatial analytic techniques for describing and understanding the spatial organization of health care, examining its relationship to health care service and access, and exploring how health care delivery can be improved. Nearest Neighborhood Analysis, Network Analysis and Weighted Sum Analysis have been employed for assessing and modeling spatial accessibility of PHC locations. The travelling time and travelling distances bands are obtained from the service area analysis with impedance calculated for the travelling time and travelling distance.The distributional pattern and the connectivity network influence the service in question, largely due to sparse distribution of tribal population occupying forest area. The analysis suggest that the population of the study area can optimally be accommodated by allocating only a few new facility but emphasis has to be given to improving the connectivity especially in the inaccessible area which are rendered as dark zone on the basis of poor road connectivity. There is the scope of reshuffling and allocating new PHCs.

Keywords: Accessibility, GIS, Primary Health Care (PHC), spatial pattern, tribal zone.

1. Introduction

Human health has been prime factor in the sustainable development of the society, irrespective of the developmental status of the society or the country. Health care system of any country or region has an important role to play for the sustainable health management. The functioning of the health care system necessarily does not depends on the simple rule of demand and supply rather it has its dependence on the accessibility factor of the population in the service area of the health care unit thus criteria of population demand cannot be the only requirement for the allocation of any health care unit. The population as such is very dynamic in terms of its spatial arrangement in the space and its cultural-behavioral characteristics. Accessibility thus, can be expressed as people's ability to use health services when and where they are needed.

The spatial pattern of health care facilities is concerned with the arrangement of the facilities across a geographical space. This could be in response to series of locational factors such as: easy access to facility from other nearby settlement, availability of approachable roads, mode of transport or impediment like water bodies, forests, rugged terrain and others. Health care decisions are strongly influenced by the type and quality of services available in the local area and the distance, time, cost, and ease of traveling to reach those services. Primary health care (PHC) is an imperative strategy to providing "health for all" and is widely acknowledged as a universal solution for improving population well-being in the world (World Health Organization and UNICEF1978).

The establishment of primary health units at the village level to bring the service as close to the people as possible, cooperation of the people in the health programme and adequate medical care for all individuals, irrespective of their ability to pay for it, were included in the Bhore Report. (Ranga Rao 1993). In India a primary health center is at grass root level in health service system delivering services in the village. Thus if it has to work efficiently, it ought to also assist the beneficiaries. PHCs should cater the population in the vicinity and hierarchy of the health services efficiently as it is not for an emergency health service. PHCs were established geographically on the basis of the demographical criteria only. The limit of service area is based on population criteria alone as a measure of the geographical accessibility, thus it act as a setback in the utilization of service. As per this criterion in India, a PHC caters to the total 20,000 population in tribal area and 30,000 in other. (MoHFW 2002)

1.1 Measuring spatial accessibility of health care and GIS

Physical accessibility is termed as a measurement of opportunities available to people in a geographical region. Access should be seen as a function of several factors, availability of services, characteristics of users and outcomes (such as change in health status or uptake of interventions of known effectiveness), while taking into account the complex and non-linear relationships between these elements (Aday and Andersen, 1981; Pawson and Tilley 1997). Physical accessibility largely depends on quantity and quality of connectivity which determines the Travelling time, Travelling distance, Speed determined by the road and its surface condition, Sinuosity, matter of choice for travelling as per road condition etc. Thus health care policies are essential in terms of the quality and quantity of services available and its associated effects on access with respect to utilization and the sustenance of the facility for continuous increase and ever-changing need of the population.

It has been observed that the inequities in the access of health care services has been existing and in some area it has increased with the time in India which according to Baru and Bisht (2010) are due to two broad responsible factors. The first set of issues concerns the weakening of public health services in terms of availability, accessibility and quality. The second concerns with increasing commercialization. Thus it is required to frame the policy looking to the aspects of strengthening the health services in terms of both, the accessible facilities which is widely accepted owing to the quality and reduce the impact of commercialisation. Health care sector is a challenging area as it involves relating geographic data on health care need, access, utilization, and outcomes with the characteristics of service delivery systems which is dependent on various qualitative and quantitative attribute. Also it requires to be weighted considering individual influence on the decisions for the best suitable plan. GIS can integrate statistical and geographic data and allow for the visualization of spatial relationships. GIS technique is efficient for analyzing health data, revealing trends and

determining relationships that might be missed in a strictly tabular format. Mapping and visualization of health disparities and their relationship to the geographical location of healthcare services can allow for better resource allocations to contrasting and underserved populations. Application of tools of GIS in health care research can encompass the geographical dimensions of access. Health care decisions of the population are strongly influenced by the type and quality of services available in the local area and the travel distance, time, cost and ease of traveling to reach those services.

Conventionally nearest neighborhood analysis and service area / voronoi maps have been employed which initially served the location-allocation problems and further the service area and network analysis gave thrust to the social research by integrating multifactorial data and also to solve "what if" problem and giving scenario based planning. While early applications of GIS in health care research focused on distribution and determinants of health and disease, more lately GIS has been applied to the planning and management of health care services (Parker and Campbell, 1998). Satia et. al. (1993) also proposed the need to reorient the primary health care programme in India away from the current strict target-achievement orientation to improving coverage, quality and content of services as the current approach has not lead to desired results.

Study by Islam and Aktar (2011) for health services in Khulna City applied to community units in the research area, allowing geographical access to be linked to people, exhibits a method for estimating the geographical accessibility of health facilities by population coverage, average travel time and distance to the closest hospital. Lee and McNally (1998) used a GIS-based algorithm for measuring physical accessibility. It is based on concepts of space–time prisms that can identify feasible opportunities under different scenarios of complex travel behavior. They seek to determine if a location can be physically reached or not. If a facility is not available on the shortest path, it can be assumed out of reach within the budgeted time (Lee and McNally 2002).

2. Study area

The study area (figure 1) comprises of the 4 tribal Taluka situated in the east of the Vadodara district of Gujarat State of India. Viz., Chhota Udaipur, Kawant, Naswadi, and Jetpur Pavi It covers total geographical area of 2,700 Sq Km encompassing 710 villages and total population of 7, 24,943 including Chhota Udaipur town which has population of 23,211. The Talukas comprises of total tribal population of 6, 15,948. Physiographically the area has rugged and undulating terrain owing to the offshoots of hilly tracts which is covered by the vegetation. Kawant Taluka has the maximum hilly terrain. The area is drained by the Orsang River a tributary of Narmada River.

Table 1: Tribal population and forest cover

Taluka	**Tribal population(% to total population)**	**Forest Cover (%)**
Chhota Udaipur	86.6	30.7
Kawant	92.5	27.7
(Naswadi	86.2	29.3
Jetpur Pavi	77.6	11.5

(Vadodara district census, 2001)

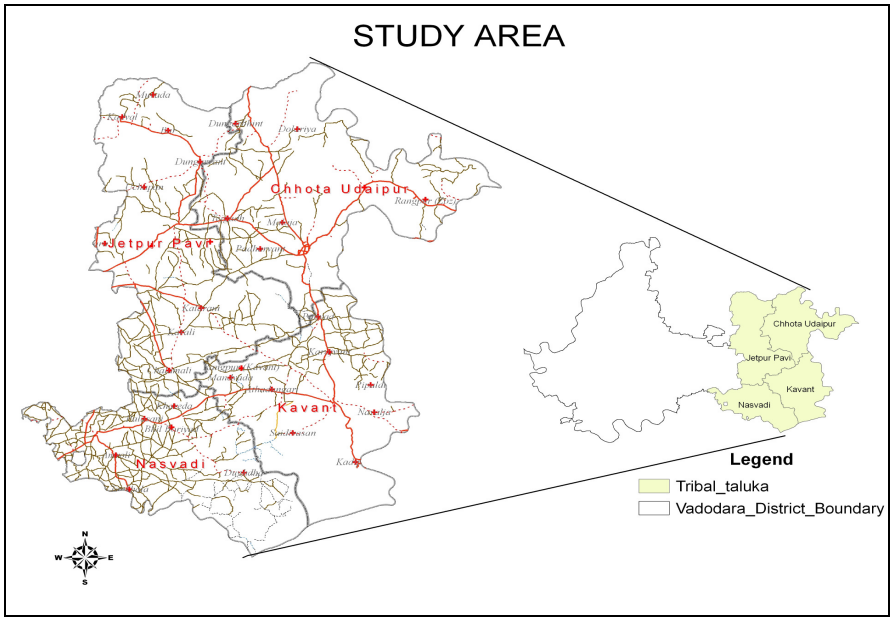

Figure 1: Map showing the Study area of Vadodara district, Gujarat

2.1 Main objective

The study emphasis on the application of GIS tools and multi parametric decision making approach for space based planning. Specifically study covers the following objectives

1. To evaluate the service area of the existing PHC.
2. To analyze the utilization aspect of the PHC.
3. To identify the regions having scope for allocating or reordering the PHC for the sustainable health delivery system.

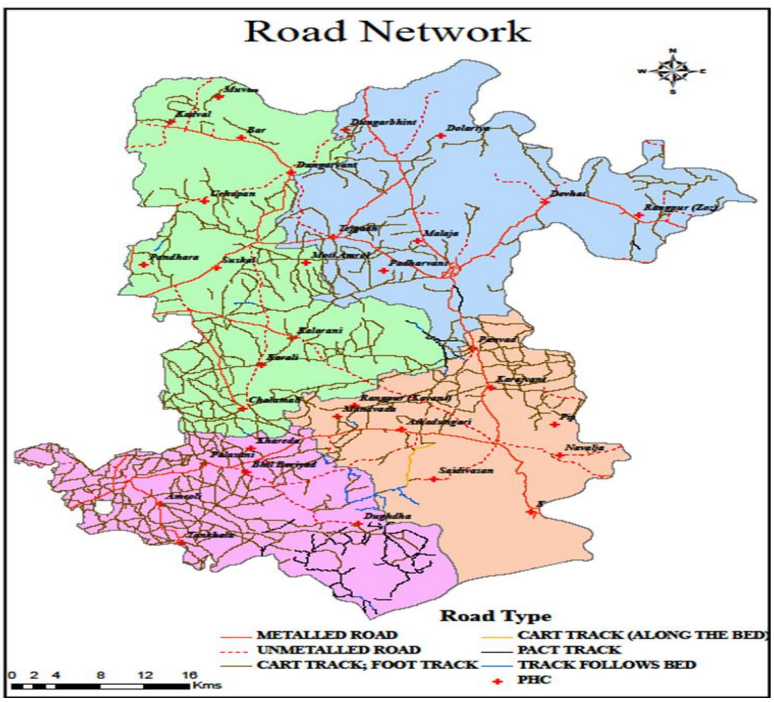

Figure 2: Road network in the study area

3. Methodology

3.1 Preparation of digital database for analysis in the GIS

The information layers such as road network, settlement area are digitised using the topographical sheets of the scale 1:50000, published by survey of India. (Fig.2) Further the Village level administrative boundary was digitised from the Vadodara district census map, census of India 2001. PHC location were marked referring to the census report, there are 33 existing PHC in the study area, exact Settlement point in village boundary were digitised using topographical sheets and were verified with the Google earth images so as to place points on the most dense settlement area in the village. All the digitisation and analysis are carried using the Arc GIS software.

3.2 Analysis

On the basis of the present geographical arrangement of the PHC and village settlement location following procedures were applied

3.2.1 Average nearest neighbourhood analysis

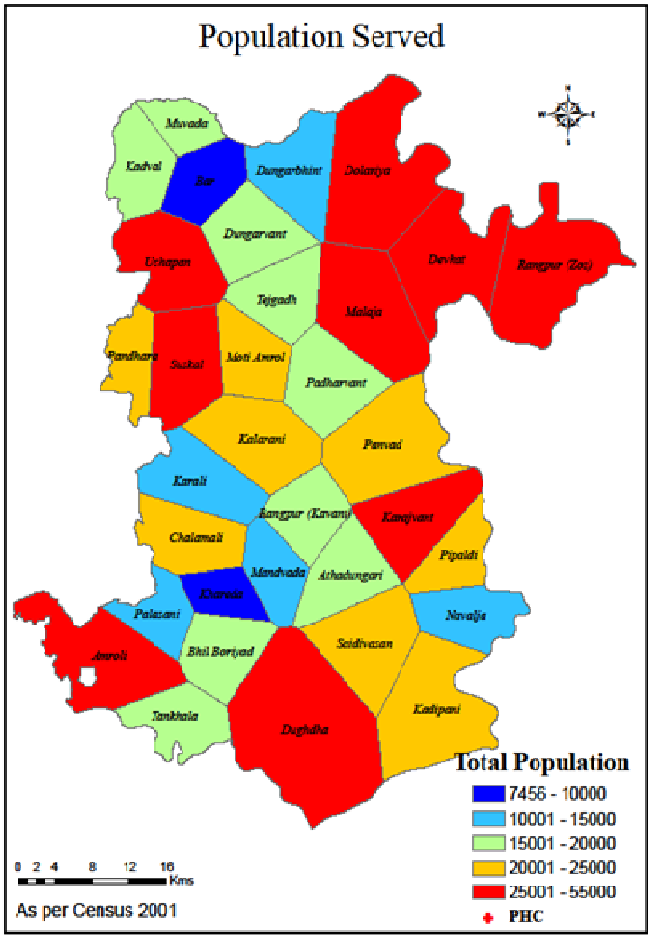

Figure 3: Population served by the PHC's

This was done to identify geographical pattern of PHCs distribution in the study area. Service areas for each PHC were obtained by Theission polygon. (Fig.2) On the basis of service area,

nearest villages covered and total population served by each PHC were obtained to recognize the population pressure existing on the individual facility as the population is considered as basic criteria for the allocation of the PHC. (Indian Public Health Standards, 2006) (Figure 3).

3.3 Network analysis

The vector layer of the Road network was converted into network dataset for this operation. Depending upon the road hierarchy and characteristic, roads were allotted an average vehicular speed. On the basis of the speed, travelling time and travelling distance required to be covered to approach the nearest facility service area were calculated, which were used as impedance in the analysis. Thus, the respective service area was obtained on the basis of travelling time and travelling distance (Figure 4). This signifies the physical accessibility towards the nearest facility with time and distance band towards the facility.

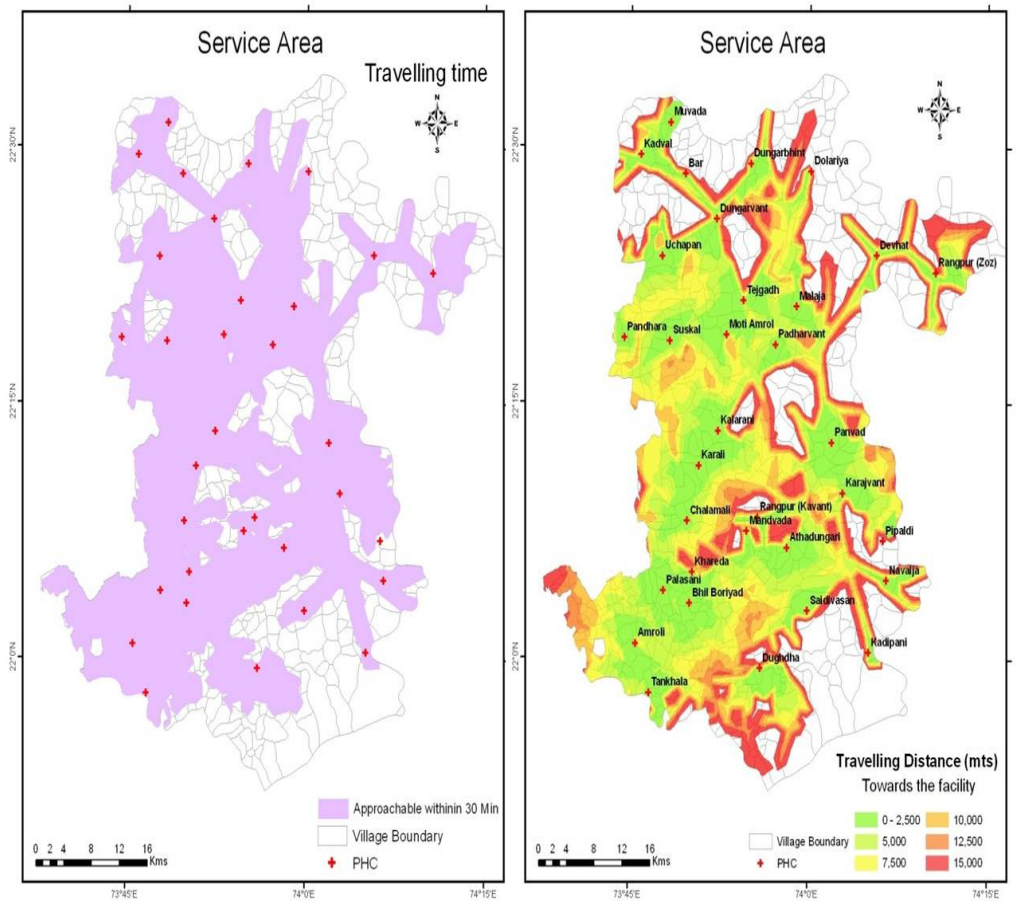

Figure 4: Service Area Based on travelling time of 30 minutes and travelling distance

In rural areas walking distance to health facilities is an important factor, because of the lack of transport. Hence, a distance of 5 km, which means one hour walking, is considered to be the maximum radius for PHC (Ranga Rao, 1993). Others have defined the distance of 1 km from the village centre as easy access (Paul et al., 2004). The time needed for reaching the facility and going back as well as the time spend within the facility further constrain access since it means a loss of income.

3.4 Weighted sum analysis

The relative influence of individual spatial factor for particular phenomenon helps in understanding the scenario, thus it is required to weigh the impacts from the planning perspective. Weighted sum analysis method was implied in which the relative scores were assigned, the higher score for the far distance and low for closeness to approach the facility. The travelling time and travelling distances bands were obtained from the service area analysis with impedance calculated for the travelling time and travelling distance. Further, assuming that by limiting the travelling time to 30 minutes (Sherman et al., 2005) will attract large numbers by saving commuting time. In the analysis all area beyond 30 minute travelling time were given high scores similarly for travelling distance, incremental bands of 2.5 km of service area were made limiting them to 15 km, the score assigned were high for the longer distance and low for short distance. As per the population criteria, population of the service area of the PHCs were also classified and higher population were given high scores as it leads to overburdened condition of PHCs.

Table 2: Scores assigned for weighted sum analysis

Distance (km)	Score	Population class	Score	Remarks
0 – 2.5	1	<20000	1	Optimally served
2.5 – 5.0	2	20,000 – 30,000	2	To
5.0 – 10.0	3	30,000 – 40,000	3	
10.0 –15.0	4	>40,000	4	Requires optimization

The three information layers viz. the travelling time, the travelling distance and the population covered were reclassified according to the scores and were converted into raster with the pixel value representing the scores for individual category in each layer. This layer were subjected to the weighted sum analysis in which each layer was given uniform weightage and as a result different zones were obtained by adding all individual scores of the layers, high scores showing inaccessible conditions and demarcating those area as dark zones for utilization aspects.

4. Result and discussion

The locational pattern of the PHC in the study area is randomly dispersed as obtained by Average Nearest Neighbor analysis refer table 2.

Table 3: Nearest neighbourhood analysis

Parameter	**Values**
No. of PHC	33
Nearest Neighbor Ratio	1.642171
Z - score value	7.06
Observed Mean Distance:	7270.6 m
Expected Mean Distance	4427.42 m

The optimum service area of the existing PHC obtained show a random coverage area, it is observed that 8 PHCs are having service area more than 100 sq km and serving total population of more than 22,000 which goes up to 51,000. This shows that all such PHCs are

overburdened serving large population as per the norms. Interestingly, all of these are situated as a peripheral service area adjoining to the other districts there by suggesting the political boundaries influencing the policies instead geographical which may be a reason for uneven distribution of the PHC.

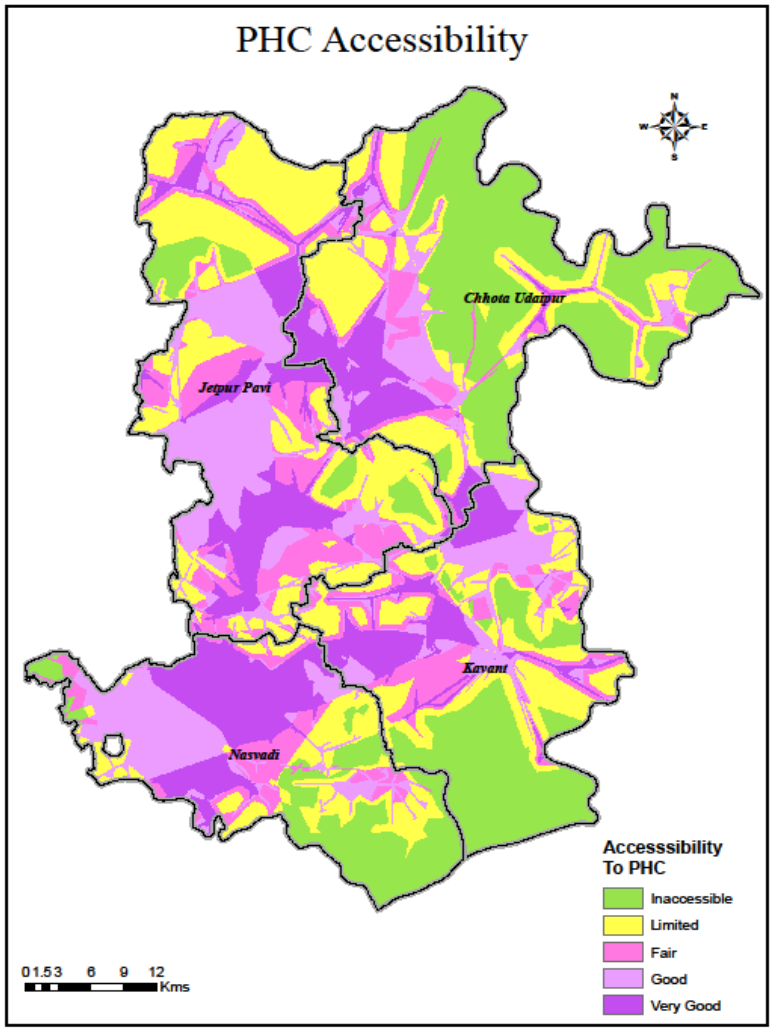

Figure 5: Zones showing levels of Accessibility

The result of the travelling cost in terms of the time and distance conveys that central and southern villages of the study area are relatively accessible as compared to the eastern and northern villages. In northern and eastern villages, the topography and the geographical population distribution play a direct control on the road network. So to conclude, topography of area acts as barrier in providing connectivity and thus the accessibility and utilization of health service. Consequently, here the road distribution defines the connectivity. In the center part it is the presence of the vegetated hill which makes this area void. The average radial distance, the distance between the health facility and the border of its service area, for SC is 2.73 km, for PHC it is 6.69 km, and for CHC it is 18.32 km (MoHFW 2002). Depending on landscape features like mountains or rivers, infrastructural conditions (type of road), mode of transport (bus, walking), and seasonal conditions (monsoon season, harvest season etc.) access to the facilities varies. The random dispersed pattern of PHC also suggests the control of heterogeneity of the study area. Thus it can be one of the areas to be considered for delivering the equitable health service to all as per WHO guidelines. The distributional

pattern and the connectivity network largely influence the service in question but the sparse population of tribal's poses real time challenge in the inaccessible locations of east and south of the study area attributed to forests.

The southern and eastern parts of the study area are rendered inaccessible in combination of the PHC availability and road connectivity. As the population of the villages which is less and so providing good connectivity network can be solution for those inaccessible areas. The limited accessible zones are the zones, where there is the scope of reshuffling and allocating new PHC as they have the population determinant as the main cause. This will require in depth investigation looking to the demographical structure and geographical aspects of the location. With aspect of physical accessibility, the location of PHC in the village settlements of the study area shows that there is limited need of reshuffling of PHC in the eastern part were the population covered by the PHC service is relatively less enabling the future demand. The other parts of the study area have good physical accessibility due to the better road network and utilization aspect can be better investigated by incorporating the socio-cultural aspect.

The analysis suggest that the population of the study area can optimally be accommodated by allocating only a few new facility but emphasis has to be given to improving the road connectivity especially in the inaccessible area which are demarcated as dark zone due to this reason.

5. Conclusion

Because where healthcare is located matters, GIS analysis of health data and healthcare service locations is valuable for describing and understanding relationships between healthcare access and health outcomes. Mapping of health data can establish patterns of health disparities. The use of advance GIS tools has proved to be boon to the researchers and planner to visualize and conceptualize the health plans and policy also the public health administrator are at the advantage of saving time and resources by application of such tools. As future scope, this study can be enhanced by adding micro level information such as demographic characteristic, landuse land cover, and slope drainage.

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