Analysis of Spatial Distribution and Accessibility of Public Healthcare Facilities by Using Geospatial Techniques: A Case of Wolaiyta Sodo Town, Ethiopia.

Amanuel Tadesse Bergene

A Thesis Submitted to the Department of Geomatics Engineering School of Civil Engineering & Architecture and Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science in Geo-informatics Engineering

Office of Graduate Studies
Adama Science and Technology University

June 2023
Adama, Ethiopia

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APPROVAL SHEET

I/we, the advisors of the thesis entitled "Analysis of Spatial Distribution and Accessibility of Public Healthcare Facilities by Using Geospatial Techniques: a Case of Wolaiyta Sodo Town, Ethiopia" and developed by Amanuel Tadesse Bergene, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Tilahun Erduno (Ph.D.)	____________________	________________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Amanuel Tadesse have read and evaluated the thesis entitled "Analysis of Spatial Distribution and Accessibility of Public Healthcare Facilities by Using Geospatial Techniques: a Case of Wolaiyta Sodo Town, Ethiopia" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics Engineering.

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Finally, approval and acceptance of the thesis is contingent upon the submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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DECLARATION

I hereby declare that Master thesis entitled "Analysis of Spatial Distribution and Accessibility of Public Healthcare Facility by Using Geospatial Techniques: The Case of Wolaiyta Sodo Town, Ethiopia" That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Amanuel Tadesse	______________	________________
Name of student	Signature	Date

RECOMMENDATIONS

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “Analysis of the Spatial Distribution and Accessibility of Public Healthcare Facilities by Using Geospatial Techniques; A Case of Wolaiyta Sodo Town, Ethiopia” prepared under my guidance Amanuel Tadesse Bergene submitted in partial fulfillment of the requirements for the degree of Mater‘s of Science in Geoinformatics. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Tilahun Erduno (PHD)	____________________	__________________
Major Advisor/Supervisor	Signature	Date

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2SFCA	Two-Step Floating Catchment Area
AHP	Analytical Hierarchy Process
CSA	Central Statistics Agency
DEM	Digital Elevation Model
EPHI	Ethiopia Public Health Institute
ESRI	Environmental Study Research Institute
HC	Health Centers
HCF	Healthcare Facility
FMOH	Federal Ministry of Health
GH	General Hospital
GIS	Geographic Information System
GPS	Global Positing System
MCDA	Multi-Criteria Decision Analysis
NNA	Nearest Neighborhood Analysis
SH	Specialized Hospital
TIFF	Tagged Image File Format
WHO	World Health Organization
WLA	Weighted Linear Combination
WSU	Wolaiyta Sodo University

ABSTRACT

Public healthcare facilities are among the most basic needs of the public and are directly related to residents' health. Many peoples who live in the periphery of most towns in Ethiopia lack efficient healthcare facilities. Wolaiyta Sodo town is one of those towns where existing healthcare facilities are not fully accessible, unevenly distributed, and scarce for peripheral dwellers a result of these most of the peoples are confronted with several problems, especially in the time of medical emergencies to get the service immediately. This study aims to evaluate the spatial distribution and accessibility of existing healthcare facilities. Further, to select new suitable sites in study areas. The spatial statistical analysis, locational quotient and nearest neighborhood analysis methods used for spatial distribution, concentration and patterns respectively at the kebele level of the town. The level of accessibility investigated by using road network service area analysis in terms of distance and time. The spatial analyst except for Digital elevation model and Land use, the rest data were analyzed through proximity analysis. The new healthcare facilities sites are selected by using GIS-based Multi-criteria analysis through the analytical hierarchy process. The data used for this study such as Road networks, Existing healthcare facilities, Population density, Slope, Manufacturing sites and land use land cover data. The results of spatial pattern analysis nearest neighborhood ratio show (NNR=1.355265) which indicates a more random distribution pattern of healthcare facilities. The service area analysis about World Health Organization 2km and 30 minutes recommended maximum distance and time to reach the healthcare facilities. Residents in Wolaiyta Sodo town could get the nearest healthcare facilities within a 2km distances accessibility are 125,934(42.51%) and 170,312(57.49%) populations are accessible in >2km distance. The time-based service area analysis result shows populations of 157,900 (53.3 %) are accessible within < 30 minutes and 138,347(46.7%) populations are accessible in > 30 minutes from the total 296,246 populations. The selected suitable site by using GIS-based Multi-Criteria Analysis method indicates that 773 ha (6.75%), 2605 ha (22.75%) and 5568 ha (48.6%) of the study area has been identified as very highly suitable, highly suitable, and medium suitable for healthcare facilities development respectively. The remaining 2180 ha (19%) and 324ha (2.92%) of the study area have been identified as very less suitable and unsuitable sites respectively. This study revealed that the healthcare facilities in the study area are unequal in distribution, which indicates that it needs redistribution and construction of additional healthcare facilities for those inaccessible areas.

Keywords: *Healthcare facilities, Spatial Distribution, Spatial Accessibility, Geospatial technology*

CHAPTER I: INTRODUCTION

1.1 Background of the study

The world is experiencing tremendous urbanization and population growth. According to a United Nations report (United Nations, 2019), the world population is expected to increase by 2 billion in the next 28 years, from 7.7 billion today to 9.7 billion in 2050. It has been. Developing countries face rapid urbanization and urban expansion (UNDESA, 2015). Sub-Saharan Africa will account for most of the world's population growth in the coming decades (World Population Prospects, 2019).

Ethiopia is the second most populous country in Africa with 107 million inhabitants (United Nations, 2017). According to the national report on housing & sustainable urban development, Ethiopia is one of the least urbanized countries in Sub-Saharan Africa. Currently, 20 percent of the total population lives in urban areas (MoUDC, 2014). However, the country has one of the highest rates of urbanization even by the standards of developing countries, which is estimated at a 4.1 percent growth rate (MoUDC, 2014).

Urbanization is caused by a rapid increase in people migrating from rural areas to towns. A growing urban population brings about changes in various social, economic, and environmental sectors (Liu, Yang, Chen et al. 2020). This means that as urban populations have grown rapidly, so has the demand for social services in local communities also increased. These primarily include healthcare facilities, education, water supply, and a wide range of cultural and leisure activities. In particular, health plays an important role in the lives of all peoples and the lives of entire nations (Birch, 2006). However, healthcare performance in a particular region depends on factors such as service availability, the number of population served, service location distribution, and socio-economic characteristics.

Throughout the world, one of the most important conceptual issues is assessing equity in healthcare distributional imbalance that there are inequalities in healthcare facilities status and access to care for different categories of people whether identified by social class as measured by income wealth, or formal education, gender, ethnicity, and spatial distribution (Mossialos, 2004). Spatial accessibility usually focuses on alternatives of the ratio of supply (provider) versus demand (population) in the administrative unit or the travel impedance between the population and health service providers (Luo and Wang et al. 2003).

The healthcare delivery system in Africa particularly in Sub-Saharan countries suffers from weak infrastructure, a lack of trained human resources, and a poor supply chain management system (Bilal,2011). In these countries, access to healthcare facilities is particularly low where the majority of the population resides. In addition, there is also an uneven distribution of health workers, which results from little availability and poor quality of health services in rural areas (Batts, 2016).

(Aday and Andersen et al. 1981) For instance, poor service availability makes it difficult for users to access the facility. Sometimes even a facility's level of service decreases due to the overwhelming number of people it must serve. The geography of access to healthcare is essential for understanding healthcare distribution inequalities. This subpar performance could have an impact on the resident's quality of life. One of the elements that can be included in Ethiopia's urban planning tools is the establishment of a healthcare facility. According to the (WHO, 1997) healthcare facility should be located based on the population index and the maximum travel time and distance (catchment area radius).

According to (Deaton, 2003) evidence has shown that among poor countries, increase in life expectancy is strongly correlated with increase in productivity and income. Increased productivity by individual or group of people in all sectors depends on the health conditions of the labor force, while improved health and quality of life depend to a great extent on the availability of, and accessibility to health care facilities at an affordable cost. GIS has a potential role in assessing the geographic distribution of health services, in particular evaluating the effectiveness of health facility coverage relevant to population density.

However, due to the limited effectiveness of plan implementation, urban development in the case of Ethiopia's urban centers is rarely meeting this standard. Moreover, developers of private healthcare facility centers in particular, in Wolaiyta Sodo town are mainly market-oriented and focus on an area where they can attract relatively residents with a better income. This can affect the spatial distribution of healthcare facilities in the town which leads to unbalanced service provision between neighboring areas such as Kebeles and the expectation for equal distribution of educational infrastructure is a major challenge (Adebola, 2011). Residents in the urban periphery have a low level of accessibility to healthcare facilities. To balance services in long-term urban social service planning, assessing the distribution level of existing healthcare services provision and accessibility is a useful approach to select suitable sites for future.

Geospatial techniques analysis is a logical method that can be applied to measure the spatial distribution and the degree to which geographical access is obtained. It has recently been used to approximate the degree of healthcare facility need or forecast healthcare demand in several studies (Al-Taiar, 2010). Accessibility analysis is a relational evaluation of services relative to potential users' demand measured within a specified distance range and using a detailed road network. This type of analysis is therefore not a simple service-to-population ratio, but also the consideration of distance and time. A key advantage of measuring accessibility is that the measurements take into account service sufficiency (capacity) concerning its location (McGrail, 2012).

To specifically analyze the characteristics of healthcare facility spatial distribution, and accessibility and select possible suitable sites for healthcare facilities in developed countries especially in USA and China studies were conducted (Rezayee, 2020;sohel rana et al., 2019; Murad, Dalhat and Naji, 2020; Carolina, 2017; Jain and Subbaiah, 2007;Ababa, 2014).

In Ethiopia, there were some studies conducted on evaluating the spatial accessibility of healthcare facilities using GIS and Remote Sensing (Tesfaye Dagne,2022; Getu Desalgne,2012; Temesgen Yene,2016). However, this study used a service area road network to analyze the accessibility in terms of distance and time by considering different recommended design speeds of the road as their type used and select new suitable site by using multi-criteria-based site suitability selection. Therefore, this study aimed to fill the existing research gap by using geospatial technology and applying GIS-based multi-criteria analysis methods to evaluate spatial distribution, concentration, patterns and identify the levels of accessibility in terms of distance and time. In addition to these to select new very highly suitable sites for public healthcare facilities in study area.

1.2 Statement of the Problem

Rapid Urbanization and the demographic explosion in the sub-Saharan African countries have created tremendous pressure on resources and public facilities (Abdel-Latif, 2007). The inequality in healthcare service provision between neighboring areas decreases spatial accessibility of the residents to get healthcare facilities. Hence, understanding the existing level of facilities distribution and accessibility has a major role in alleviating the problem

(Yi 2004; Inobeme & Ayanwole,et al. 2009). Making healthcare facilities sufficient, equal, and accessible is as seen as one of the key goals in healthcare facilities delivery systems (Powell, 2003).

Ethiopia with collaboration to world health organization (WHO, 2017) has been involved in measuring accessibility to healthcare facilities working with several academic institutions (Black, 2004). Accordingly, to assess the scale of the problem, it is necessary to realistically analyze the distribution pattern and accessibility and how the differences with the standard set by the Ministry of Health (WHO, 1997).

Wolaiyta Sodo Town is one of the oldest towns in Ethiopia that is formed more than 100 years ago (WDA Bulletin, 2008). Due to geographical location, the town has a center to all other southern administrative zones and a business center to them this leads the town to have greater population attraction and settlement of newcomers from different regions of the country (Andarge, 2016). The population of Wolaiyta Sodo town shows high growth. Within 29 years the population size has grown from 10,245 in 1984 to more than 296,246 in 2015 (Socio-economic profile of Sodo, 2023). When the urban population rapidly increased, the demand of the community for health care facilities also increased.

Lack of geographical distribution of healthcare facilities in the Sodo town a large number of the population could not get healthcare services near their residence. Therefore, the town needs additional healthcare facilities to satisfy future population demands for healthcare access. Hence, Geospatial techniques based multi- criteria decision analysis for new healthcare facilities site selection is an important step for the town's economics and growth strategy.

In addition to this study area associated with unplanned development and declining basic services, especially health sites (Sanni, 2010). The problem is predictable to get worse in the coming years due to the huge construction of buildings, roads and less attention given to accessibility. However, there is continuous report for healthcare facilities service by Sodo town health department twice a year but analyzing accessibility of existing healthcare facilities to residents in study area by using geospatial techniques cannot be studied. This study aimed to give insight of the detailed analysis for healthcare facilities accessibility and their geographical distributions, concentrations and patterns that could help to differentiate the level of accessibility in the town and to select new very highly suitable sites by using geospatial techniques.

1.3 Objective of the Study

1.3.1. General Objective

The general objective of the study is to analyze the spatial distribution and accessibility of public healthcare facilities in Wolaiyta Sodo town by using Geospatial techniques.

1.3.2. Specific Objectives

In line with the broad objective, the specific objectives are to:

- determine the spatial distribution, concentration and patterns of the public healthcare facilities in study area.
- identify accessibility level of public healthcare facilities to residents in terms of distance and time
- identify the main determinant factors for public healthcare facilities development in study area
- identify suitable sites for public healthcare development using MCDMs in study area.

1.4. Research Questions

1.How to determine the spatial distribution, concentration and patterns of public healthcare facilities in the study area?

3. To what extent those public healthcare facilities in Wolaiyta sodo town are accessible?

4. What are the main determinant factors for public healthcare facilities site selection development?

5. Which sites are more suitable for the development of public healthcare facilities in study area?

1.5 Scope of the Study

The spatial scope of this study is limited to the Wolaiyta Sodo town administrative boundary. Whereas, the contextual scope of this study is focused on evaluating the spatial distribution and spatial accessibility of existing public healthcare facilities specifically hospitals and health centers and to select new suitable site to them by using Geospatial techniques.

1.6 Significance of the Study

The scientific method of identifying spatial distribution and accessibility helps the decision makers to differentiate the accessible and inaccessible areas in the town. This helps to make a balanced distribution by taking any measures to balance it according to recommended by ministry of health in terms of distance and time by differentiating inaccessible area. Next to this, this study analyzed new suitable sites depending on this selecting a good site improves the accuracy of the decision of makers for planning and building the new healthcare facilities and to increase performance. If a private or government institution asks site decision-makers to establish healthcare facilities in the town then the site decision-makers can quickly identify potential sites using a constructed suitability map. Therefore this study avoided delaying decision-makers and wasting time during selecting safe healthcare facility locations. In the aspect of community making research like this primarily benefit the community that is affected by the distribution of the service centers among their residential areas in Wolaiyta Sodo Town. Furthermore, the research serves as a resource for other academics interested in conducting additional research in Wolaiyta Sodo town.

1.7 Organization of the Thesis

This thesis is organized into five chapters. The first chapter is the introduction part, which includes a background of the study, a statement of the problem, objectives of the study, research questions, significance of the study and scope of the study. The second chapter highlights a review of literature that consists of both research-related review literature and conceptual review literature. The third chapter gives a description of the study area and the methodology of the study. The fourth chapter talks about data analysis, results, and discussion of the study. The final part presents the conclusion and recommendations.

CHAPTER II: LITERATURE REVIEW

This study focuses on determining the spatial distribution, concentration, patterns, and how existing healthcare facilities are accessible throughout the town in terms of distance and time then to select the new suitable public healthcare sites in the study area. The purpose of this literature review is to present past studies on the issue to serve as the foundation for the study's arguments and assertions. Following a thorough search by the researchers, this section presents the associated literature and studies. Various perspectives on the subject from past researchers are offered and discussed. The theoretical and conceptual framework was built based on the aims and statement of the problem presented in chapter one in this chapter.

2.1 Spatial Location of Urban Facilities

Urban public facilities are crucial resources that enhance the all-around development of man and his environment (Pan, 2016). Especially, healthcare facilities infrastructure is an important aspect that needs to be earnestly developed in society. The healthcare facilities is an important part of public facilities since it provides services to the people and also impacts individuals who do not have access to its use in the area. The catchments area for which the service is provided; the location area of the users/serviced population; the availability of appropriate area of land/site (topography, area). In Ethiopia, locational standards (Table 2.1) for urban infrastructure provision have been set in the urban planning and implementation manual to guide the planning process (FMOH, 2017).

Table 2.1 Level, Requirement and Location of Healthcare Facility Standards in Ethiopia

Level	**Catchment area**	**Served Population**
Health post	300M^2	3,000-5,000
Health Center	2,000-5,000 M^2	15,000-40,000
Primary Hospitals	5,000 – 10,000 M^2	60,000- 100,000
General Hospital	20,0000 M^2	1,000,000- 1,500,000
Tertiary Level Specialized Hospital	30, 000 M^2	3,500,000 – 5,000,000

Source: FMOH Healthcare tier and standards, 2017

2.2 Spatial Distribution of Urban Public Services

The conventional method to define spatial accessibility is to use population ratios concerning the health services that fall within predefined, administrative boundaries. However, two main assumptions should cause concern as they are generally not valid in real-world care-seeking scenarios. (J. Luo, 2014) i) residents within the administrative region all have equal access to health resources within the region; ii) residents of a region do not travel beyond the boundaries of their region to seek care elsewhere (Wing and Reynolds et al.1988). Employing different levels of data aggregation (resolution) can strengthen the validity of one of these two assumptions but not both at the same time. For example, using more disaggregated data (smaller areal units) will make the first assumption more realistic but would also decrease the validity (Sobhani, 2014).

The spatial distribution of healthcare facilities in the Chikun local government area of Kaduna State Nigeria by employing GIS and GPS to map existing ones, and evaluate adequacy based on World Health Organization standards (Sanni, 2010). The Kernel Density tool calculates the density of features in a neighborhood around those features, which was articulated by (Sedenu, 2016) to show the geographic distribution nature of the existing healthcare facilities. It can be calculated for both point and line features. Conceptually, a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point and diminishes with increasing distance from the point. Measuring the compactness of a distribution provides a single value representing the dispersion of features around the center. The value is a distance, so the compactness of a set of features can be represented on a map by drawing a circle with a radius equal to the standard distance value to creates a circle polygon (Venter, 2022).

A common way of measuring the trend for a set of points or areas is to calculate the standard distance separately in the x- and y-directions. These two measures define the axes of an ellipse encompassing the distribution of features (ESRI, 2022).

(Arokoyu and Weje et al. 2015) carried out work on the spatial distribution of health facilities in the South-South, Nigeria. The spatial inequality and the polarization of development sought to determine the extent and nature of variation in socio-economic development in the 123 Local 12 Government Areas (LGAs) of south-south, Nigeria. carried out work on the spatial distribution of public health care facilities in GOMBE LGA for assessing the spatial distribution of the public health facilities.

2.3 Spatial Concentration of Urban Public Services

The idea of spatial concentration is used to measure how well public facilities in different parts of an urban area are balanced (Jahan and Oda et al. 2000). It considers population distribution and computed the value of the location quotient (LQ) ratio. The location quotient is a device for comparing a percentage share of a particular facility within a part of the town with its percentage share of the total population. It helps to quantify and benchmark the degree of the relative concentration of activity in the analysis of area localization. The values of the result of spatial concentration can be categorized into above-average, average, and below-average. This concept has been used in different studies for instance, in spatial analysis of urban amenities to evaluate the distribution of public facilities as a tool for measuring progress towards sustainable neighborhood environments (Parry, 2013).

2. 4 The Concept of Spatial Accessibility

2.4.1 Accessibility

Accessibility in healthcare facilities can be defined as the potential or ease for certain health services to be reached and utilized by the patients or demands (Elikan 2013). Accessibility often refers to spatial or physical accessibility and is concerned with the complex relationship between the spatial separation of the population and the supply of healthcare facilities it is influenced by both spatial factors (geographical location and travel distance) by different means of transportation and non-spatial parameters such as socio-economic status, populations health status, financial status, perception about health and health care system and traditional customs (Guagliardo, 2004).

Accessibility can be defined in terms of mobility, which includes many spatial and non-spatial attributes as well as temporal constraints, of individuals or groups (Neutens 2015). Accessibility can be measured by either Euclidean and Manhattan distance travel (driving or walking) time or travel cost. Accessibility can be described as travel impedance (travel distance or travel time) between patient location and healthcare service points (Guagliardo, 2004).

2.4.2 Access

Access is defined as the ability or ease for patients to access services, healthcare providers, or facilities (Guagliardo, 2004). Access can be described as the degree of fit between users and services. The degree of fit might be influenced by the availability, accessibility, accommodation, affordability, and acceptability of service (Penchansky and Ph et al. 2015). Furthermore, access is linked with the demographic, socio-economic, and cultural characteristics of the population, the locations of the healthcare facilities, and the transportation network. In other words, access is patterned both spatially and socially (Field, 2004). Spatially, the more resources that are provided into an area for use the greater the likelihood that people will use those resources and live in that surroundings. Access to an existing resource or facilities (e.g. a hospital or a road network) is generally understood as the capacity of an individual to obtain a service when it is needed (Samat and Shattar et al. 2014).

2.5 Spatial Accessibility Measures

Spatial Accessibility measures indicators give different values that rank accessibility to facilities from high accessibility to inaccessibility. They can also be used to classify facilities in terms of their peripherally and centrality locations (Schurmann & Talaat et al. 2002). As there is no agreement about the concept of accessibility, measuring accessibility differs from one study to another depending on its aims and the nature of factors that are used to measure accessibility, which might be quantitative or qualitative factors. These factors can be time or distance of travel, available transport modes, people characteristics, activities characteristics, etc. As a result of this disparity in the causes of measurement of accessibility, many accessibility measures have appeared in different disciplines.

2.5.1 Use of Geospatial Techniques for Spatial Accessibility Measures

The use of Geospatial techniques for the measurement of spatial accessibility is well established and has been applied in many areas including retail site analysis, transport, emergency service, and healthcare planning. By using one Geospatial software GIS is well suited to measuring spatial accessibility to health care as they contain the core components needed for such analysis namely: data capture storage, management and manipulation tools for both spatial and attribute (textual) data, core analysis algorithms such as buffering, overlay, proximity analysis, shortest path and raster cost-distance analysis and mapping and visualization tools to communicate the results of the analysis. (Parker and Campbell et al. 1998)

The traditional approach to measuring access, for years, has been the number of facilities to population ratio as a measure of availability by the distance or time traveled to the nearest or by the number of facilities in a geographic area. These measures, however, do not handle properly such peculiarities as the use of services in other communities, the failure to use the nearest facility, overlapping coverages, and redundant services (Rosero-Bixby, 2004)

Geospatial accessibility refers to a geospatial barrier those are distance, cost, and time between the demand and supply; in the context of health care, geospatial accessibility presents an obstacle to accessing health services (Munoz, 2012). Geospatial accessibility analysis is strongly linked to supporting effective planning and decision-making strategies (Tanserl, 2006). According to (Munoz e, 2012), health planning and evidence-based policy development can be improved when the performance of the health system is well understood from a geospatial perspective.

2.6 Factors Affecting Healthcare Facilities Accessibility

Healthcare accessibility is affected by different factors like the availability of roads, land cover type, topographic condition, population distribution, and mode of transportation used to reach health facilities (Dassah,2018). Some of those factors are stated below.

2.6.1 Road

The availability of modern transportation facilities can bring a positive impact on health conditions by increasing options for commuters and creating connections to health services. On the other hand, lack of access to affordable transportation facilities is the main contributor to health disparities (LCEF, 2011). The availability of roads allows for covering an extensive catchment area, which are located very far from existing healthcare facilities. Its presence increases area coverage, and the number of population served by healthcare facilities and vice versa.

2.6.2 Topography

Topography is an important barrier to healthcare services. It can influence both positively and negatively, the speed of travel time for land cover types. Its impact is more pronounced if patients are walking or using bikes to reach health facilities from their homes. The effect of topography will be positive if a patient is walking or biking downward from his home to healthcare facilities. Such a type of effect is called anisotropic effect and analysis of such effect is anisotropic analysis (Murad, 2011).

2.6.3 Land use Land Cover

Land use Land cover types and their spatial distributions have an impact on healthcare accessibility. Different land cover types have different traveling speeds.

Table 2.2 Land Use Land Cover Traveling Speed

Classes	Label	Maximum traveling speed (km/h)
1	Bare area(Walking)	5
2	Dense Vegetation or Forest (Walking)	2
3	Low-density Vegetation (Walking)	3
4	Primary Road (Vehicle)	60
5	Cobble Road(Vehicle)	40

Source: (WHO, 2018)

2.7 Travel Impedance

The two most common types of distance measure used for determining spatial accessibility in the literature are the Euclidean distance (more often known as straight line distance) and the Manhattan distance (distance along two sides of a right-angled triangle, the base of which is the Euclidian distance). Literatures suggests that the Manhattan network distance measure is more appropriate than euclidean distance in measuring gridded road networks in urban areas, but argues that the shortest network travel time is more accurate than any other distance measure.

(Longley,2010) works on the shortest distance between two points either directly or along a network (such as roads) can be used to derive travel time. Attributes such as length, speed, restrictions on travel direction, and level of congestion can be taken into account when calculating travel time.

2.8 ArcGIS Network Analysts

ArcGIS and its network analyst tool are the main software that is going to be employed in this study. ArcGIS for Desktop and Network Analyst will help the county make more informed decisions (Monica Pratt and Wondwosen et al. 2016).

2.8.1 Service Area Analysis

Network Analyst: ArcGIS Network Analyst is a powerful extension that solves a variety of problems with spatial network-based analysis including routing, travel directions, closest facility, OD-Cost Matrix analysis and service area analysis (ESRI, 2005, cited in Wondwosen 2016). Using a sophisticated network data model, users can easily build networks from their geographic information system (GIS) data (Shaliniet, 2014).

2.9 Suitability Analysis

Suitability analysis, or site selection, is a GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of suitability analysis is that each aspect of the landscape has intrinsic characteristics that are to some degree either suitable or unsuitable for the activities being planned. Suitability is determined through systematic, multi-factor analysis of the different aspects of the terrain. Suitability analysis can be performed using either vector or raster data but is often performed using the latter. Different data layers are created that correlate to various physical, cultural, or economic factors that would be important for site selection analysis. The results are often displayed on a map that is used to highlight areas from high to low suitability (Hofstee and Brussel et al. 2019)

2.9.1 New Health Facilities Site Selection Requirements Criteria in Ethiopian

The following criteria for new health facility site selection requirements are set in Ethiopia by the Ministry of Health (MoH, 2018).

1. The entry point to the healthcare facilities shall be clearly defined from all major exterior circulation modes (roadways, bus stops, and vehicle parking).
2. The entrance and exit of the healthcare facilities shall be easily accessible, clearly marked/labeled, and located.
3. Boundaries of the healthcare facility between public and private areas shall be well-marked and distinguished. And visible and understandable signage and visual landmarks for orientation shall be provided.
4. Healthcare facilities shall be located away from unordinary conditions of undue noises, smoke, dust, or foul odors, and shall not be located adjacent to railroads, freight yards, grinding mills, chemical industries, gas depots, and waste disposal sites.
5. The locations of a health center shall comply with all national and state-level regulations applicable to health facilities.

2.10 GIS-Based Multi-Criteria Decision Analysis

Multi-criteria decision analysis (MCDA) is a group of techniques for structuring and evaluating decision alternatives based on multiple attributes and objectives (Voogd, 1983).

MCDA approaches can integrate numerous notions of decision problems. They enhance communication and expedite the process of reaching concurrence and determining the most suitable options (Boroushaki and Malczewski et al.2006). The most commonly used subjective weighting methods are as follows.

2.10.1 The Point Allocation Method

This is one of the simplest methods used to determine criteria weights according to the priority of criteria; a decision-maker allocates a certain number of points to each criterion. The more points a criterion receives, the greater its relative importance (Golaszewski, 2012). In this scenario, the decision maker is asked to allocate 100 points across the criteria under consideration. The total of all criterion weights must sum up to 100. This method is easy to normalize. However, the weights obtained from the use of the point allocation method are not very precise and the method becomes more difficult as the number of criteria increases to 9 or more.

2.10.2 The Direct Rating Method

The direct rating method is a type of approach in which the decision maker first ranks all the criteria according to their importance. The rating does not constrain the decision maker‘s responses as the fixed point scoring methods do. It is possible to alter the importance of one criterion without adjusting the weight of another (Last and Arber et al. 1989).

2.10.3 Pairwise Comparison Method

The pairwise comparison method was established by (Satty,1977) for determining factor weights in the Analytic Hierarchy Process (AHP). This method involves pairwise comparison to create a ratio matrix. It takes the pairwise comparisons as input and produces the relative weights as output. The weights are determined by normalizing the eigenvector correlated with the maximum eigenvalue of the reciprocal ratio matrix (Malczewski, 1999). The pairwise comparison method involves the three following steps.

1) Development of a pairwise comparison matrix

The method uses a scale with values ranging from 1-9 to rate the relative. References for two criteria see (table 2.3) below.

Table 2.3 Scale for Pairwise Comparison

Degree of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderately more important	Experience and judgment slightly favor one activity over another
5	Strongly more important	Experience and judgment strongly favor one activity over another
7	Very important	An activity is strongly favored and its importance demonstrated in practice
9	Very strongly more important	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For the value between the above value	Intermediate value between adjacent scales for inverse comparison.

Source: Saaty (1980)

2) Computation of the criterion weights

The computation of weights involves three operations, first, sum the values in each column of the matrix, then each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Afterwards, computation of the average of the elements in each row of the normalized matrix should be made which includes dividing the sum of normalized scores for each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared.

3) Estimation of the consistency ratio

Estimating the consistency ratio helps determine if the comparisons are consistent or not. The process uses a several-step process. First, determine the weighted sum vector by multiplying the weight for the first criterion times the first column of the original pairwise comparison matrix, then multiply the second weight times the second column, the third criterion times the third column of the original matrix, finally, sum these values over the rows. Second, determine the consistency vector by dividing the weighted sum vector by the criterion weights determined previously. Third, compute lambda (λ) which is the average value of the consistency vector, and Consistency Index (CI) which provides a measure of departure from consistency and has the formula below:

$$CI = \frac{\lambda - n}{n-1}$$

Finally, the calculation of the consistency ratio (CR) which is defined as follows:

$$CR = \frac{CI}{RI}$$

2.10.4 Ranking Method

This is one of the simplest approaches to assigning criteria weights. The criteria are usually ranked from best to worst importance. There are three approaches to calculating weights using the ranking method. They include the rank sum, the rank exponent, and the rank reciprocal. In the rank sum, the weights are computed from the individual ranks normalized by dividing the sum of the ranks. The formula for rank sum determination can be expressed as (Odu and Raszkowska et al. 2013).

2.11 Brief Overview of Some of the Studies

Accessibility is the key element within the health care delivery system. Ideally, all should have equal access to quality health. Such equal access has come to be recognized as essential to public health as individual health status (Culyer and Wagstaff et al.1993, Oliver and Mossialos et al. 2004.

In United State of America by (Rayad Bont, 2010) studied the spatial distribution and accessibility analysis of public healthcare facilities by using buffering methods in this study the researcher analyzed the level of distribution and accessibility by generating the equal distance buffer polygons for each healthcare facilities depending up the generated polygon coverage determined the level of distribution and accessibility. However, this study differentiated the level of accessibility the area that buffered polygon not covered area and over lapped area are considered as un accessible area current study solve this problems by using road network based service area analysis method.

In Africa some studies by Samuel and Innocent (2015) in Benin City, Nigeria carried out work on the spatial distribution of health facilities. The spatial inequality and the polarization of development sought to determine the extent and nature of variation in socio-economic development in the 123 Local 12 Government Areas (LGAs) of southern part of Nigeria carried out work on the spatial distribution of public healthcare facilities in GOMBE LGA for assessing the spatial distribution of the public health facilities. In this study to measure the average travel distance to the nearest providers apply the straight line distance between the population point and the location of the health provider. However, travel routes are rarely straight lines in reality. It also cannot fully represent clusters of health providers in an urban setting and ignores the availability dimension of access.

Next studies by (Talami and Ngi et al. 2015) in Mombasa town, Kenya under the title of Integration of GIS and Multi-criteria Evaluation for Public healthcare site selection. Researchers examined the use of GIS with multi-criteria evaluation and AHP to select healthcare selection. They have used twelve parameters to identify a suitable site for healthcare location. The total population of the study area was considered rather than excluding population under 5 years old as mentioned in the above previous research gaps. So that, the researcher agreed with the idea of Talami and Ngig because of using the total population of the study area for healthcare site selection. Using GIS, multicriteria, and AHP techniques both researchers are achieved the set objective. Using this technique for suitable site selection for public healthcare has a significant role, so that for this research also this method is selected.

In Ethiopia, Various studies such as (Gebreselassie and P. J Rao et.al, 2021; Dejen and Soni, et al 2019, and Andarge, 2016) in Addis Ababa undertaken to examine the spatial distribution and accessibility of healthcare facilities observed that the major issue with healthcare in the country is not so much with the quality of services rendered but mal-distribution of facilities, it is often not easily accessible to those in need. In this study, the researchers focused on whole Addis Ababa population data and the number of primary hospitals at the city level which is distributed and located geographically by analyzing the accessibility and distribution only considering primary hospitals. Next to this study can use two–step floating catchment area method (2SFCA). The 2SFCA overcomes the restriction of using pre-defined geographical boundaries. However, the limitation of 2SFCA is mainly found in assuming a health provider inside a catchment area is accessible and one outside the catchment area is inaccessible, which tends to be arbitrary, ignoring the possibility of overlapping areas in coverage. But the current study uses the service area network which is more flexible and uses the road network to determine each existing healthcare facility in the study area.

(Getu Desalegn,2020) Studies accessibility of public service in Yeka Sub City. The title was" Location Allocation Analysis For Public healthcare services using Gis Techniques: A Case Of public healthcare facilities Accessibility in Yeka Sub-City, Addis Ababa, Ethiopia”. This study also uses GIS to measure spatial accessibility to primary schools in terms of distance and time and try to select suitable sites for schools. This study, the current study measures the spatial accessibility to health centers in terms of distance and Time, but this study differs in types of service and number of suitable selection criteria.

(Tesfaye Dagne ,2022) Studies Evaluating the spatial accessibility of public health care using geospatial techniques: a case of Lemi Kura sub city Addis Ababa, Ethiopia in this study used a service area road network to analyze the accessibility in terms of time and distance and try to select the site for inaccessible areas in the town but the current studies different from this study by considering different design speed of the road due to their road types recommended and to select the site for the inaccessible area not deciding only the result obtained from accessibility to decide.

Other researcher (Abebaw, 2010) in Bahir Dar City, Ethiopia studies on Health Facilities Distribution Mapping. This research mapped the distribution of health facilities point pattern analysis was conducted to evaluate the distribution of health facilities in the sub-city. Nearest neighbor statistics were calculated for the evaluation of the pattern of the distribution of the cases. The nearest neighbor ratio (R) calculates the distance between one point to its nearest points. In this study, the researcher can determine the distribution pattern but cannot determine whether the distribution meets the country-level standards in the given boundary. The current study added the distribution and determined the required minimum standard of Ministry of Health and WHO standards in the given boundary.

(Temesgen Yane,2016) in Jimma Town, Ethiopia has studied health center distribution mapping. The title was “Health Facilities Distribution Mapping in Addis Ababa, Ethiopia”. The researcher focuses on the ratio of the population to health centers of government and private. The study did not concentrate on distance and time, that has been covered by peoples in the study area. But this study differed from Temesgen's studies, in that the current study focus on the national standards that must be covered by peoples to get health service.

CHAPTER III: MATERIALS AND METHODS

3.1 Description of the Study Area

Wolaiyta Sodo is the administrative capital of Wolaiyta Zone in the Southern regional State of Ethiopia, which is located 328 Km South and 151 Km of South West of Addis Ababa and Hawassa, respectively. The town is located at 6°51'18" N latitude and 37°48'51" E longitude.

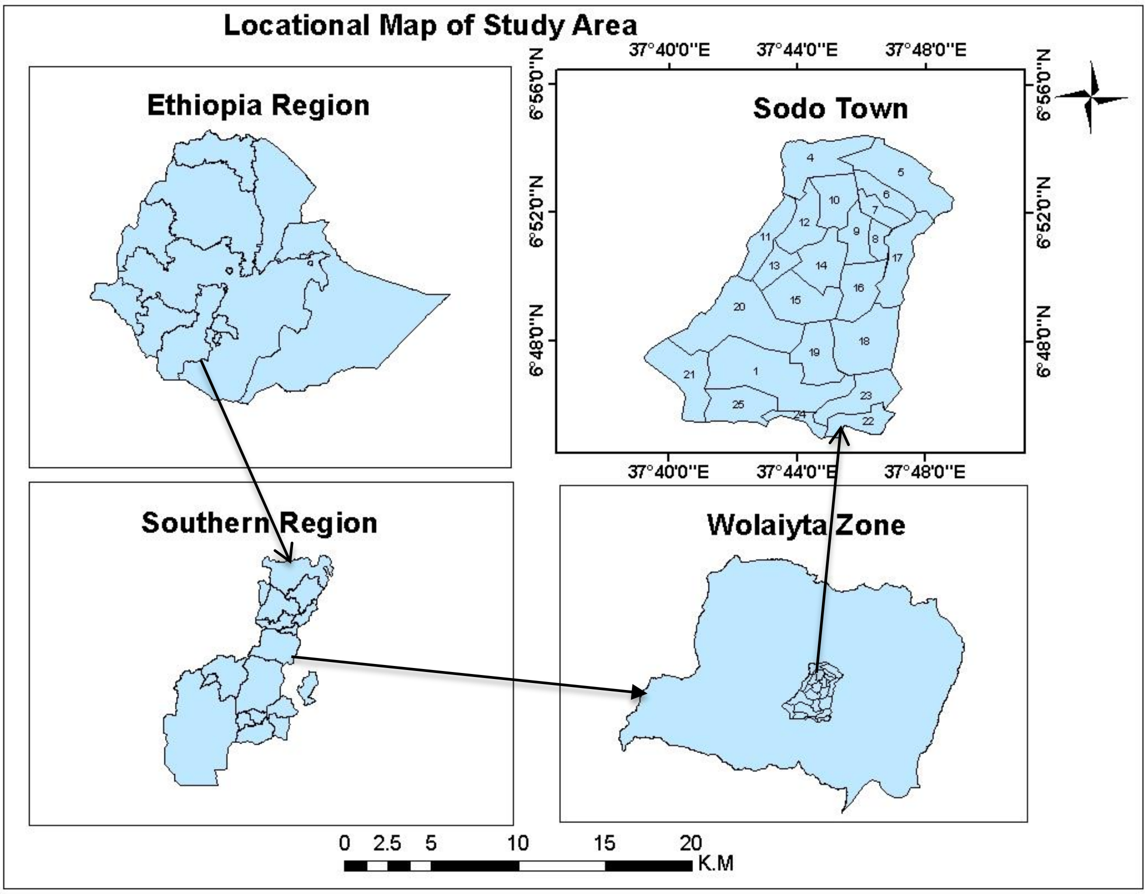


Figure 3.1 Map of the study area

Currently, the total area of the town is about 114.45sq.km and is divided into three sub-city ("Kifle-Ketama") namely Arada, Mehal Ketema, and Merkato that includes 23 administrative kebeles within this three sub city. This new Sodo Town boundary was established and approved in 2022. The town connects commercially important zonal capital such as Arbaminich (capital of Gamo Zone), Sawulla (capital of Gofa Zone), Hosanna (capital of Hadiya Zone), and Shashemane town (capital of Western Arsi Zone). Based on the 2022 Population Projection by the Wolaiyta Sodo town health department, this town has a total population of 296,246 from whom 146,005 are men and 150,241 are women. Sodo is located in the tropics at high altitudes; Sodo possesses a well-moderated

Subtropical highland climate, with a pronounced pattern of wet summers and dry winters. Despite being located in the Northern Hemisphere, Sodo is cooler in the "summer" than in the "winter" due to much high rainfall in the high-sun season, a phenomenon on common to Sodo town.

3.1.1 Population

According to the last three consecutive censuses conducted in the country, Wolaiyta Sodo Town showed a large increase in population. In the first Ethiopian population and housing census, which was held in May 1984, Sodo Town had a population of 10,245. The second population and housing census conducted in 1994 reported that Sodo Town had a total population of 38,626 of whom 19,713 were males and 18,913 were females. According to the third Ethiopian population and housing census which was conducted in 2007 (the most recent year for which data are available) 76,050 people of whom 38,375 males and 37,675 females were inhabited in Sodo. Based on this the projected population of Wolaiyta Sodo Town in 2021 was 204,121 of whom male103, 260 and female 100,861 and Sodo Town 2021 added 8 new kebele the total population in this kebele 64,326 from whom 30,543 males and 33,783 females the total population of Sodo Town total in 2021 is 288,447 then in 2023 Wolaiyta zone health department projected population is 296,246.

Table 3.1 Population of Wolaiyta Sodo Town from 1984 to 2023 Development

Year	1984	1994	2007	2021projected by CSA	8Added new kebele	Projected Pop total by (STHD) in 2023
Population	10,245	38,626	76,050	204,121	64,326	296,246
Total population in 2023 = (2021 prjected + 8 kebeles Pop in 2021) their sum projected in 2023 = 296,246						

Source: (Wolaiyta Zone Sodo Town Health Department, 2023)

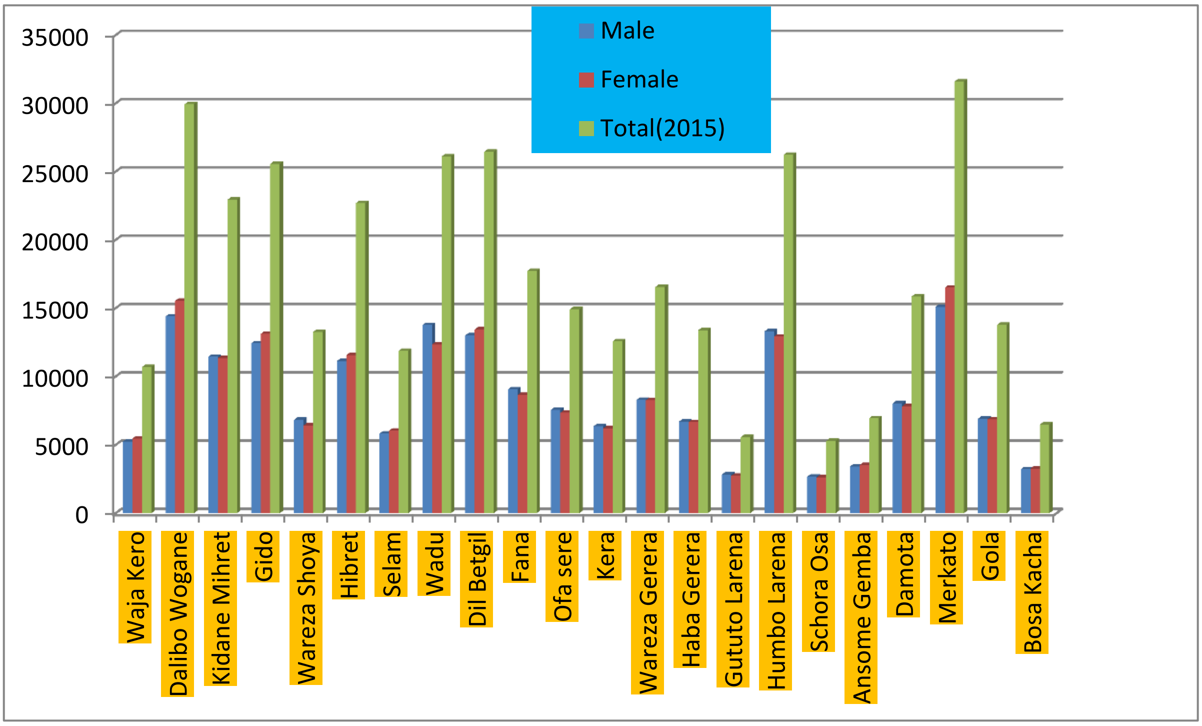
According to the Wolaiyta Sodo Health Department, the projected population in 2015 has been implemented with a total population of 296,246 in the Town of 23 kebeles. And the population distribution in each kebele has been depicted as shown in the table (see Table3.1), among those kebele, Kebele twenty is the most populated with a population of 31,596, and kebele seventeen is the least populated kebele with a population of 5,291.

Table 3.2 The Study Area Population Distribution

No	Kebele	Male	Female	Total(2015)	% Ratio to total pop	Sex ratio (F: M)
1	Waja Kero	5,237	5,455	10, 692	2.7	1.042
2	Dalibo Wogane	14,400	15,541	29,941	12.67	1.046
3	Kidane Mihret	11,445	11,352	22,797	5.78	0.992
4	Gido	12,439	13,126	25,565	10.79	1.055
5	Wareza Shoya	6,832	6,424	13,256	3.37	0.940
6	Hibret	11,130	11,562	22,692	5.76	1.039
7	Selam	5,831	6,041	11, 878	3.21	1.036
8	Wadu	13,760	12,342	26, 102	6.61	0.897
9	Dil Betgil	13,012	13,442	26,454	6.70	1.033
10	Fana	9,067	8,654	17, 721	4.50	0.955
11	Ofa sere	7,562	7,359	14,921	3.78	0.973
12	Kera	6,365	6,213	12,578	3.19	0.976
13	Wareza Gerera	8,288	8,269	16,557	4.19	0.998
14	Haba Gerera	6,710	6,670	13, 380	3.39	0.994
15	Gututo Larena	2,829	2,740	5,569	1.41	0.969
16	Humbo Larena	13,310	12,921	26,231	6.65	0.971
17	Shchora Osa	2,671	2,620	5,291	1.34	0.981
18	Ansome Gemba	3,417	3,524	6,941	1.76	1.031
19	Ofa Gandaba	6,734	6,646	13,380	3.39	0.987
20	Damota	8,040	7,820	15, 860	4.02	0.973
21	Merkato	15,088	16,504	31,596	12.32	1.017
22	Gola	6,921	6,863	13,784	3.50	0.992
23	Bosa Kacha	3,224	3,265	6,489	1.65	1.013
	Total	146,005	150,241	296,246	100	

Source: (Socio-economic profile of Sodo Town, 2023)

Sex Ratio: The majority of the residents of the town are women as the existing data portrays. As the projection of population made on the bases of 2007 G.C housing and population census results in Sodo Town.



Source: Wolaiyta Zone Health Department (WZHD, 2023)

Figure 3.2 Population of Sodo Town at Kebele Level

3.1.2 Climate

The climate of Wolaiyta Sodo town is described based on the type of rainfall and temperature. The mean annual rainfall is greater than 1550mm per year. Most of the town of Sodo experiences a Woina dega (warm to cool) type of climate (SNNPR, Bureau of Regional Meteorology Annual Report, 2021) except the Mt. Damot environment of the town, which experiences a colder climate. The south and southwest peripheries of the town experience transitional types of climate (warm to hot) (woina dega to kolla) mainly due to the effect of a southeast rift valley that crosses the surrounding woreda (Delibo Wogen and Humbo Taballa) and runs into the lowlands of lake Abaya and Chamo, the rift valley lakes.

3.1.3 Drainage

Many streams originate from the foot of Mount Damot which disseminate into the town in different parts. Among them, the main ones include; Hamassa, Kalte, Kokate, Bichere, Lintala, Waja River, etc. The study region is demarcated in the west and east with two permanent rivers (Hamassa and Waja Rivers). Most of the rivers are intermittent during the dry season except Hamasa and Waja rivers, which drain into Lake Abaya. As the town is situated at a higher elevation, flood hazard risks remain common and serious in damage, particularly during rainy seasons.

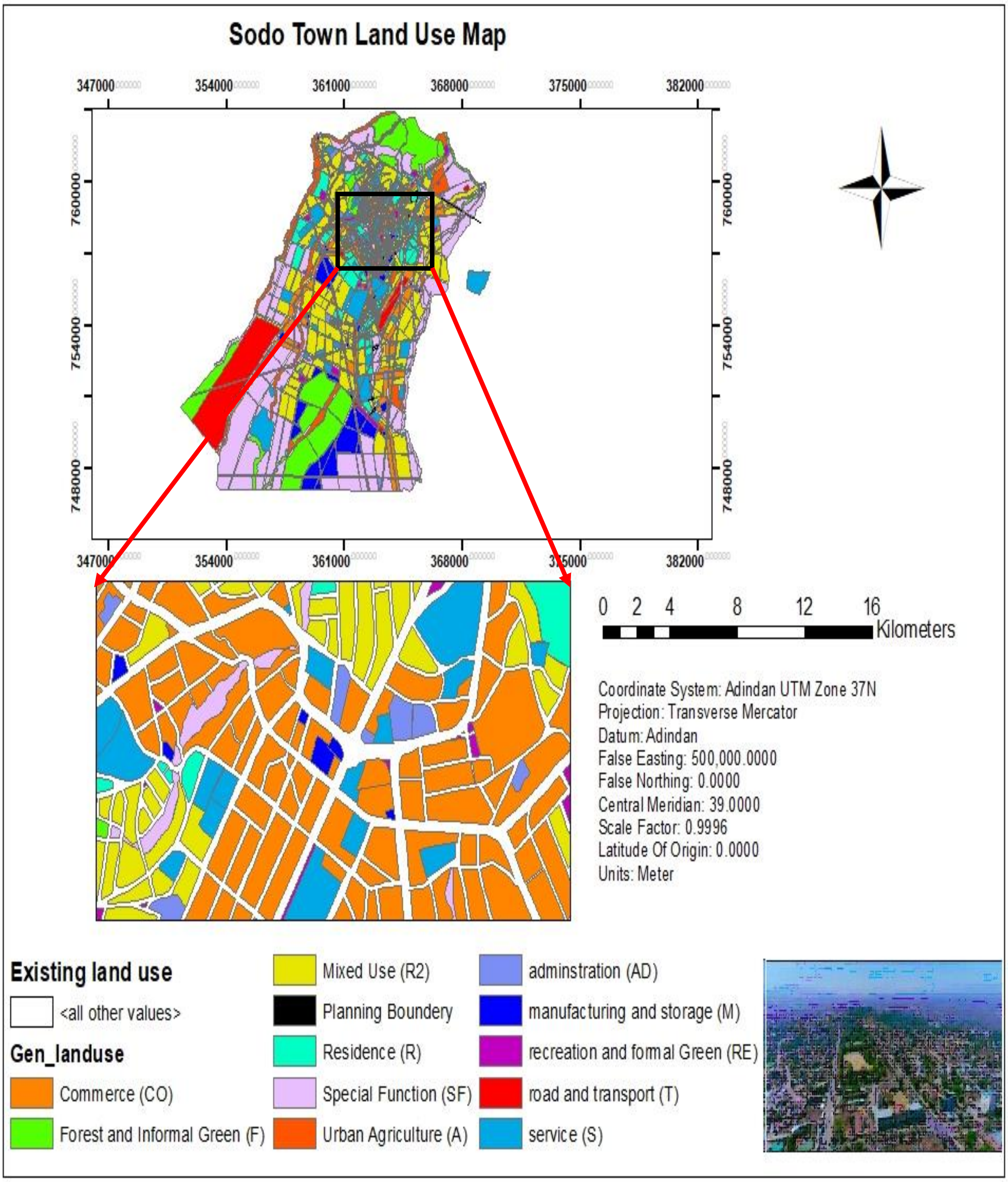
3.2 Land Use Classes of Wolaiyta Sodo Town

Several land use types are recognized in irregularly mixed appearance with one another throughout the whole study area. Before health facility allocation is made, it is important to identify every part of the area under study and for what purpose it is used because it helps to isolate where the demand (request) for the health center exists and where there is not, where the demand is high and where it is low, etc.

Table 3.3 Land Use of Sodo Town

No	Land use types	Code used	Area(sq.km)
1	Administration	Adm	2.45
2	Commercial	Co	7.78
3	Cultural and Social welfare	CSW	0.855
4	Education	Ed	11.60
5	Healthcare Facilities	Hf	6.80
6	Infrastructures and Utilities	ISU	7.50
7	Manufacturing and Storage	MS	8.85
8	Mixed Residential	MR	3.8
9	Municipal Service	MuS	6.58
10	Open Space	OS	4.30
11	Plantation and Urban Agriculture	PUA	4.50
12	Recreational	Rc	2.64
13	Religious	Re	4.85
14	Residential	Res	10.40
15	Road Network	RN	5.20
16	Special Use	SU	13.30
17	Under Construction	UC	1.80
18	Vegetation	Veg	2.80
19	Mixed forest	Mf	1.30
Total			114.45

Source: Wolaiyta Sodo Town Infrastructure and Land Use Plan Office,2022



Source: Wolaiyta Sodo Town Infrastructure and Land Use Plan Office, 2023

Figure 3.3 Land Use Type Map of Sodo Town

3.2.1 Road Network

One of the most important land use types to be studied in this research work is the road network existing in the study area. A road is a transportation route that determines the degree of importance of another land use type by increasing the accessibility of that area.

There are five major categories of roads connected in the town namely asphalt, cobble-stone, gravel, paved, and unpaved.

Table 3.4 Major Roads Categories which Covered in Wolaiyta Sodo Town

SN	Road Type	Class	Length(Km)	Percentage%
1	Asphalt	1	60.43	23.46
2	Cobblestone	2	74.56	28.94
3	Gravel	3	56.63	21.98
4	Paved	4	16.65	6.46
5	Unpaved	5	49.35	19.16
Total			257.62	100

Source: Wolaiyta Sodo Town Cadaster Office,2022

3.3 Image Classification

Image classification is important to convert image data to thematic data. According to the Author (Li, 2014), the overall objective of image classification procedures is to automatically categorize all pixels in an image into land-use/land-cover classes. The image data was preprocessed in ERDAS Imagine,2015 and standard image processing techniques such as image extraction, rectification, atmospheric correction, radiometric correction, and classification were used for the analysis of satellite imageries. Image classification was performed by the maximum likelihood algorithm methodology for the extraction of land use in the study area.

3.4 Slope, Hillshade, Aspect, and Land Use Land Cover of the Study Area

12.5 DEM data from ALOS PALSAR Earth data source used to generate Slope, Hillshade, and aspect map of the study area and satellite image 10m resolution used from sentinel-2 USGS earth explorer for LULC of the study area. Landscaping is a big factor in analyzing the time it takes to use a road network, to visit health facilities by car or on foot and has little or no such impact on travel (See Figure 3. 4) below.

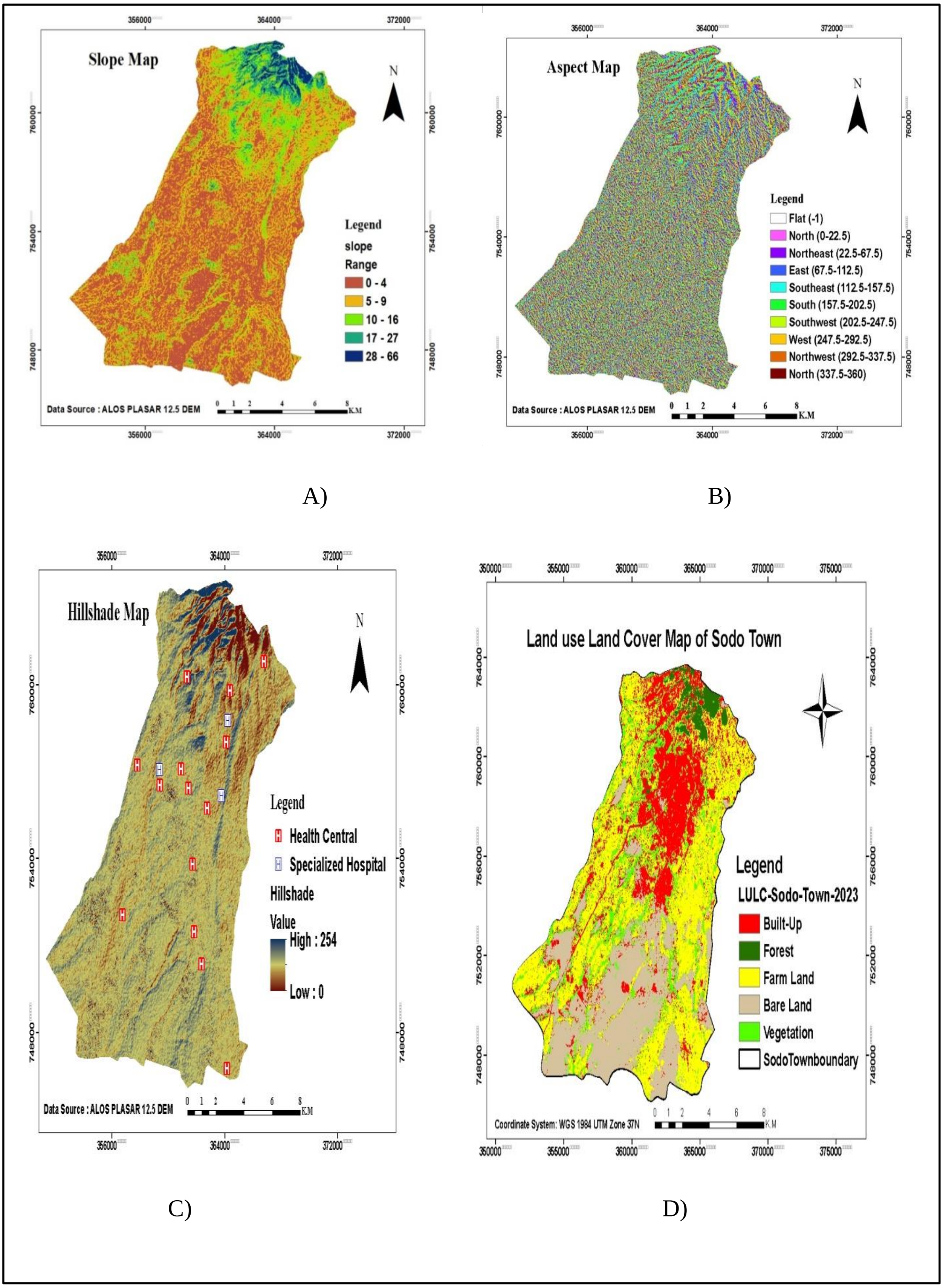


Figure 3.4 A) Slope Map B)Aspect Map C) Hillshade Map D) LULC Map of Sodo Tow

3.6 Data Sources and collection methods

3.6.1 Data sources

This study used data from both primary and secondary sources, including both spatial and non-spatial data from actual fieldwork and secondary (ancillary) data. The table below describes the data required, the types of data used in the study, the formats and where the data were gathered from, and the year of data recorded or collected are detail shown in the table (table 3.5) below.

Table 3.5 Data Source, Collection Methods, and their Uses in the Study

No	Data	Sources	Data type	Uses	Year
1	Satellite Image (Landsat-8 Res,30M)	USGS	TIFF	Identifying LU/LC	2023
2	DEM (12.5Resolution)	ALOS PALSAR	Raster	To generate slope/Aspect/Hill hade	2014
3	Road network	Sodo Master Plan	Shape file	Modify existing road Network	2022
4	Parcel Map of Sodo	Sodo Town cadaster office	Shape file	Distinguish residential parcels from the others	2022
5	Administrative maps of Sodo	Sodo Town Master Plan	Shape file	For defining the study location	2022
6	Population data	Sodo Town Health Department	Secondary data	Know Subject population	2023
7	Existing Healthcare Facilities location	Collected by the researcher using Garmin GPS	Coordinate X,Y,Z	To analyze distribution, used as criteria of suitability	2023
8	Location of Manufacturing sites	Collected by the researcher using Garmin GPS	Coordinate X,Y,Z	Used as criteria of suitability	2023

3.6.2 Methods of Data Collection

Methods of data collection involve primary data collection and secondary data collection. To obtain all documents for the study, numerous strategies are used formally and informally in the data-gathering procedure. There are two types of data collection procedures used: primary and secondary data collection.

Primary data collection

Field data is obtained by conducting direct surveys of the field such as the health facilities coordinate point collecting; this can be done with the use of handheld (Garmin GPS) with the accuracy of 2m to obtain the coordinates of Wolaiyta Sodo Town Health centers, General hospitals and specialized hospitals base transceivers stations (BTS) and coordinate points of manufacturing sites in the study areas. These coordinate points of the location used as criteria for site suitability selection analysis.

Secondary Data Collection

One of the most noticeable advantages of using secondary data analysis is its cost-effectiveness. Because someone else has already collected the data, the researcher does not need to invest any money, time, or effort into the data collection stages of his or her study. But need to check the correctness of data and its legal sources. Data obtained from other sources such as existing healthcare facilities in Wolaiyta Sodo Town. The ancillary data that will be used in this study are administration boundary, road data, and satellite imagery of 30m resolution. Another method of data collection used in this study was an Interview with Organizations: The interview method was used to collect secondary data. Healthcare facilities data were acquired from MoH sourced from EPHI and CSA population data of the town confirmed from Wolaiyta Zone Health Department.

3.7 Software and Materials Used

The software and materials used in this study were selected based on their capability to solve existing problems in achieving the predetermined objectives. To achieve the objective of the study different software and materials were used. As a result, image processing and classification activities on satellite pictures were performed using software such as ERDAS IMAGINE 2015. Google Earth was used to digitize a road, as well as to check the accuracy of the land use/land cover class. The ArcGIS 10.8 software package was also used to do rasterization, intersection, reclassification, weight overlay, and factor map development.

Table 3.6 Software/Material Used

S/N	Software name	Version/sources	Purposes
1	ArcGIS	10.8//ESRI	Data storage, process, and Map preparation
2	Erdas Imagine	V 2015/	Image Pre- Processing
3	Global Mapper	V 20.2	Processing DEM
4	Google Earth	V 7.3	Verification of timely updates images /accuracy assessments.
5	Idrisi Selva	V 17.02/open sources	AHP weighted rank/compute pair-wise comparison
6	Ms-Office	2016	Writing papers and reporting results
7	BM SPSS	22	For correlation analysis, tabulations and graphical representations
8	QGIS	V 3.30.3	For calculating time in service area analysis by considering different road type speed.
9	ENVI	V 5.1	For Land use Land Cover Classifications

3.8 Methodology

3.8.1 Techniques for Data Modifications (Preparation)

Two significant actions are undertaken in this subtopic. Firstly, adjustments for errors, irregularities, and absence. Secondly preparation of the refined data for the requirements (preconditions) of the analysis part. Therefore, data editions like corrections, modifications, deletions, substitutions, etc. were made deeply during data preprocessing. These tasks of data preparation are categorized into two phases as follows.

First Stage: The health districts, as catchment areas are not commonly available. Instead, administrative boundaries Kebele’s were used for the study. Healthcare facility center common in both attribute and spatial reference from all of the sources are selected and reserved and those with no spatial reference frame particularly that are observed from CSA data are omitted.

Second Stage: This stage works on readjustments and changes of the road network data and the land use of the study area. Road network data that are originally received from the sources cannot be directly applied as input for the analysis. Therefore it was obligatory to change from the original file format to the format type supposed to use. ArcGIS Network Analyst uses the road network to find its analysis result. But Sodo Town's local road network data were available in only area shapefiles that bound the areas covered by it.

Hence primarily and secondary roads the centerlines of this network data are traced from the existing and digitized data through editing tools in ArcMap and further modifications and additional road network parts are also added. After all editing activities are finished Sodo Road network Topology (i.e. geodatabase Topology) is built. The topology is controlled by some rules incorporated in it for further refinements of interconnections of all the lines that participated in it. The road network analysis function was applied to compute the service area, closest facilities, and OD-Cost Matrix analysis based on distance and time interval. According to the ERA technical standards (ERA,2018), travel speeds are set according to the quality of the road, i.e. 60, 40, and 5 km/h for primary, secondary, and walking speeds used in this study respectively. Accordingly, the road network data layer in the study area has been Fig. 3.6 shows the workflow of topology building for the Wolaiyta Sodo Town road network.

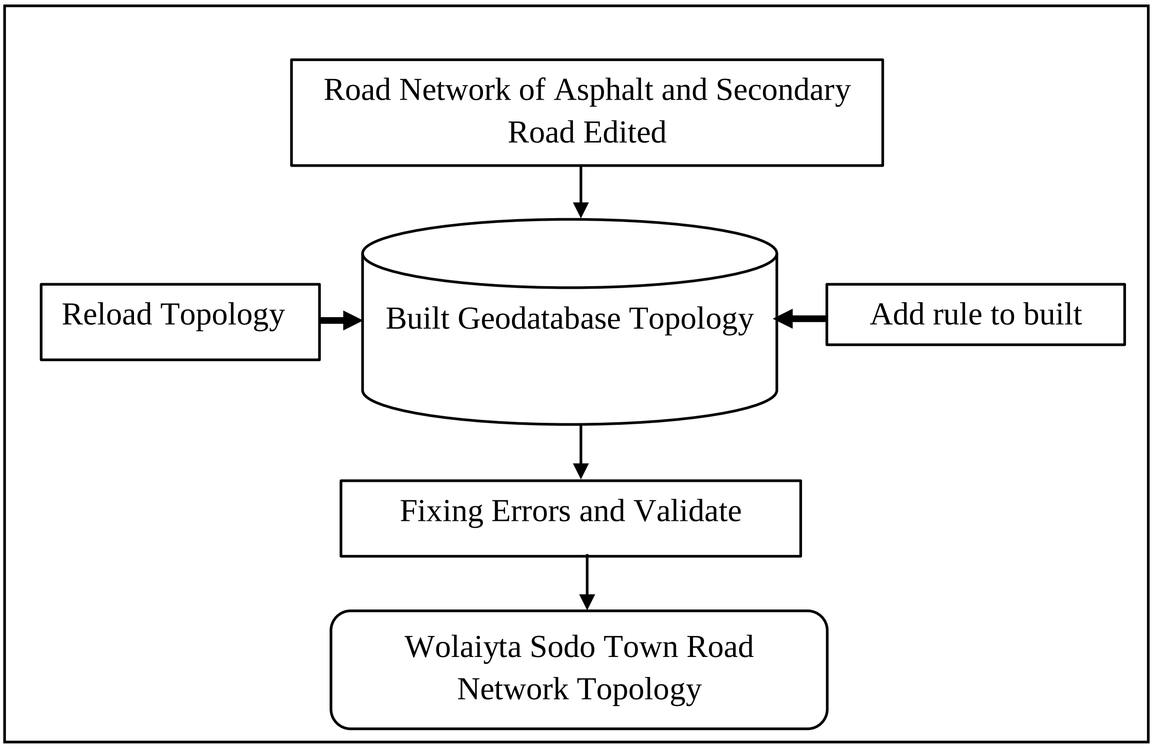


Figure 3.6 Geodatabase Topology Building Workflow

The street Network is topologically pure in its connectivity and the next step is to build a network dataset that is used directly as an input for the analysis part. And the network dataset is the pillar on which the analysis is made. The network can be created either from only involved line features (i.e. street data) or including both points and areas in a similar fashion made in the topology. Some elements are simultaneously created with the network dataset. But the importance of the elements depends on many factors such as traffic flow, overpasses, tunnels, the complexity of the roads and their hierarchy, etc. These elements are junctions, edges, turns, restrictions, stops, barriers, and centers. But in this study, only the former three are dealt with (Junctions, Edges, and Turns). Fig. 3.7 shows the workflow of the W/Sodo Town network dataset.

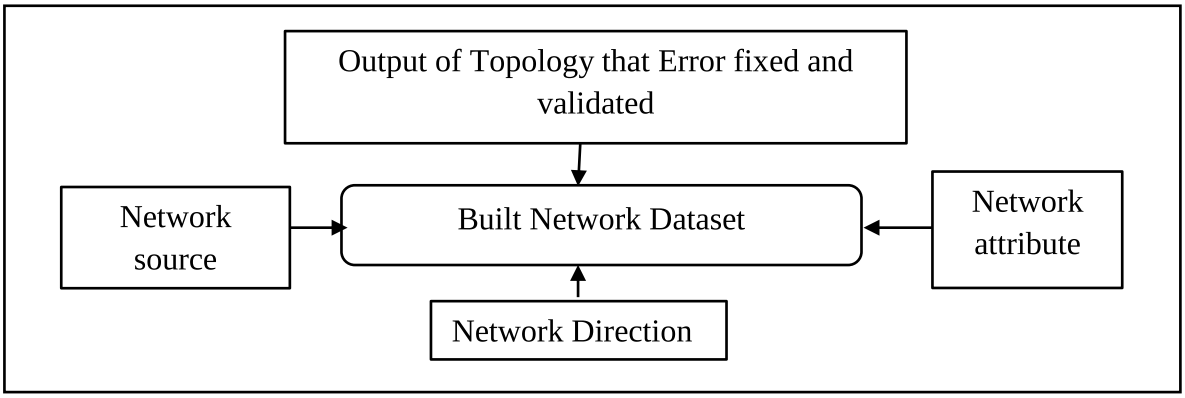


Figure 3.7 Network Dataset Building Workflow

3.9 Methods of Data Analysis

3.9.1 Accuracy Assessment

The term accuracy is typically used to express the degree of correctness of a map or classification in thematic mapping from remotely sensed data. The increased usage of remote sensing data and techniques has made geospatial analysis faster and more powerful; however, the increased complexity also creates increased possibilities for errors (Dağıstanlı, Turan, and Dengiz 2018). Therefore, the assessment of the accuracy of mapping generated from remote sensing data is a critical and essential step in the classification process (Dagistanli et al., 2018). The error matrix is the most common tool in terms of determining the accuracy of the classification results (Olofsson et al. 2014). User accuracy, producer accuracy, overall accuracy, and Kappa statistics were then derived from the error matrices for LULC classes. According to(Moller-Jensen,1997), Kappa analysis is a discrete multivariate technique used in accuracy assessments. In other words, Kappa analysis is a standard component of accuracy assessment and is considered a required component of most image analyses(Congalton ,1991).

Producer's Accuracy (Errors of omission): Producer‘s Accuracy measures the percentage of correctly classified pixels from sample data or indirectly indicates errors of omission for a particular class. Producer‘s accuracy was calculated by dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for that category (the column total). It is calculated as:

Producer‘s Accuracy = $(\frac{Ci}{Ct})*100$..**(1)**

Where, Ci = correctly classified sample locations of the reference data or column and Ct = total number of sample locations of the column.

User’s Accuracy (Commission error): user‘s accuracies are computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). This result is a measure of commission error. It is calculated as:

User‘s Accuracy $= (\frac{Ri}{Rt})*100$.. **(2)**

Where, Ri = correctly classified samples in the row and Rt = total number of samples in the row.

Overall Accuracy: Overall accuracy was computed by dividing the total diagonal (i.e., the sum of the correctly classified sample units) by the total number of sample units in the error matrix. This value is the most commonly stated accuracy assessment statistic.

Overall Accuracy = $(\frac{Sd}{n})*100$... **(3)**

Where, Sd = sum of values along diagonal and, n = total number of samples.

Kappa Coefficient: Kappa coefficient can be used as another measure of agreement or accuracy. Kappa was used to measure the agreement or accuracy between the remote sensing-derived classification map and the reference data as indicated by the major diagonals and the chance agreement. This was indicated by the row and column totals. Kappa values can range from +1 to –1. But, as there should be a positive correlation between the remotely sensed classification and the reference data, positive values were expected. Landis and Koch (1977) took the possible ranges for kappa into three groups: a value greater than 0.80 (i.e., 80% and above) represents strong agreement; a value between 0.40 and 0.80 (i.e., 40%–80%) represents moderate agreement; and a value 0.40 (i.e., 40% and below) represents poor agreement.

$$K\hat{} = \frac{\sum_{I=1}^{r} xii - \sum_{i=1}^{r}(xi+x+i)}{N^2 - \sum_{I=1}^{r}(xi+x+i)}$$ .... **(4)**

Where r = number of rows in the error matrix; Xii = the number of observations in row I and column I (on the major diagonal); Xi+ = total of observations in row I (shown as marginal total to right of the matrix); X+i = total of observations in column I (shown as marginal total at bottom of the matrix) and N = the total number of observations included in the matrix.

3.9.2 Spatial Concentration

The spatial concentration directly reflects the inequality of service provision between Kebeles. The extent of concentration of health centers and hospitals between Kebeles was analyzed by considering the distribution of the population. In this context, the Location Quotient (LQ) method by (Billings and Johnson et al.2012) was adopted. It was used to measure the extent of the health care and hospitals that have been provided for particular Kebele relative to the whole town. In other words, LQ was computed using Eq. 1 to quantify and benchmark the degree of the relative concentration of health centers in the analysis of area localization.

$$LQ = \frac{n/p}{N/P} \qquad (5)$$

Where n, p is the number of health centers and population in particular Kebele; N and P are the numbers of healthcare facilities and population in the town, respectively.

• <1, the concentration of the Health center in a particular Kebele is less than that of the town as a whole.

• LQ = 1 or close to 1, indicates self-sufficiency, which means the health center in a given Kebele is exactly sufficient to meet the local demand.

• LQ >1, the per capita availability of health centers in a particular Kebele exceeds that of the town as a whole

Further, to investigate the relationship between population and the number of health centers, the Pearson Product Moment Correlation Coefficient technique was applied to the data.

3.9.3 Spatial Distribution and Patterns

In assessing the spatial distribution of the public health facilities in the study area, all the facilities were determined and maped, and the distribution pattern of the health facilities was mapped on the map in the Arc-Map environment to show the distribution pattern.

With each health facility located as point features, the attribute data of each facility which were already compiled in MS Excel were linked with the spatial data. To calculate the density of features in a neighborhood around those features The Kernel Density analysis was used to show the healthcare distribution in the study area and to determine the spatial distribution pattern Nearest Neighbour Analysis (NNA) was used to analyze whether the distribution of the Public health facilities in this area is clustered, random or dispersed additionally to analyze the distribution nature Mean Center, Standard Distance, Directional Distribution and Central Feature of the Health Care Facilities was used in spatial statistics tool.

Where

$$ANNI = \frac{Do}{De}$$

And $D_o = \frac{\sum_{i=1}^{n} d_i}{N}$ $D_e = \frac{\mathbf{0.5}}{\sqrt{\boldsymbol{n/A}}}$.. **(6)**

di equals the distance between feature and its nearest neighboring feature. n corresponds to the total number of features A the spatial extent of the expected area In this regard, the distribution of the features being analyzed is considered as:

Clustered if ANNI < 1

Dispersed if ANNI >1

The z-score and p-value results will be used to measure statistical significance to determine whether or not to reject the null hypothesis. Because it indicates that rather than a random pattern, the features (or the values associated with the features) exhibit statistically significant clustering or dispersion. For the Average Nearest Neighbor statistic, the null hypothesis states that features are randomly distributed. The Z-score of indicates the maximum probability that the distribution likelihood could be the result of random chance. It was calculated as:

SE = $\frac{0.26135}{\sqrt{N^2/A}}$.. **(7)**

The p-value is the probability that the observed spatial pattern is created by some random process. When the p-value is very small, it means it is very unlikely (small probability) that the observed spatial pattern is the result of random processes, so the null hypothesis can be rejected. But how small enough? To answer this question, the table 3.7 below shows the critical P-values and Z-scores for different confidence levels used in this study.

Table 3.7 P-value and Z-score for Different Confidence Levels

Z-score (Standard deviations)	**P-value (Probability)**	**Confidence level**
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

In analyzing the spatial distribution and its patterns this study used the population data within each Keeble of the town and total health facility with their types and location of in which kebeles those health centers, private specialized hospitals, and general hospitals firstly determined. Next, the Ministry of Health and WHO recommended population requirements for the existing health facility in the town are evaluated and analyzed by using the Arc GIS spatial statistics tool. These tools analyze the geographical distribution pattern of health facility location mean center, standard distance, and directional distribution is analyzed. This spatial distribution, concentration and pattern analysis methodology is shown in Figure 3.8 below.

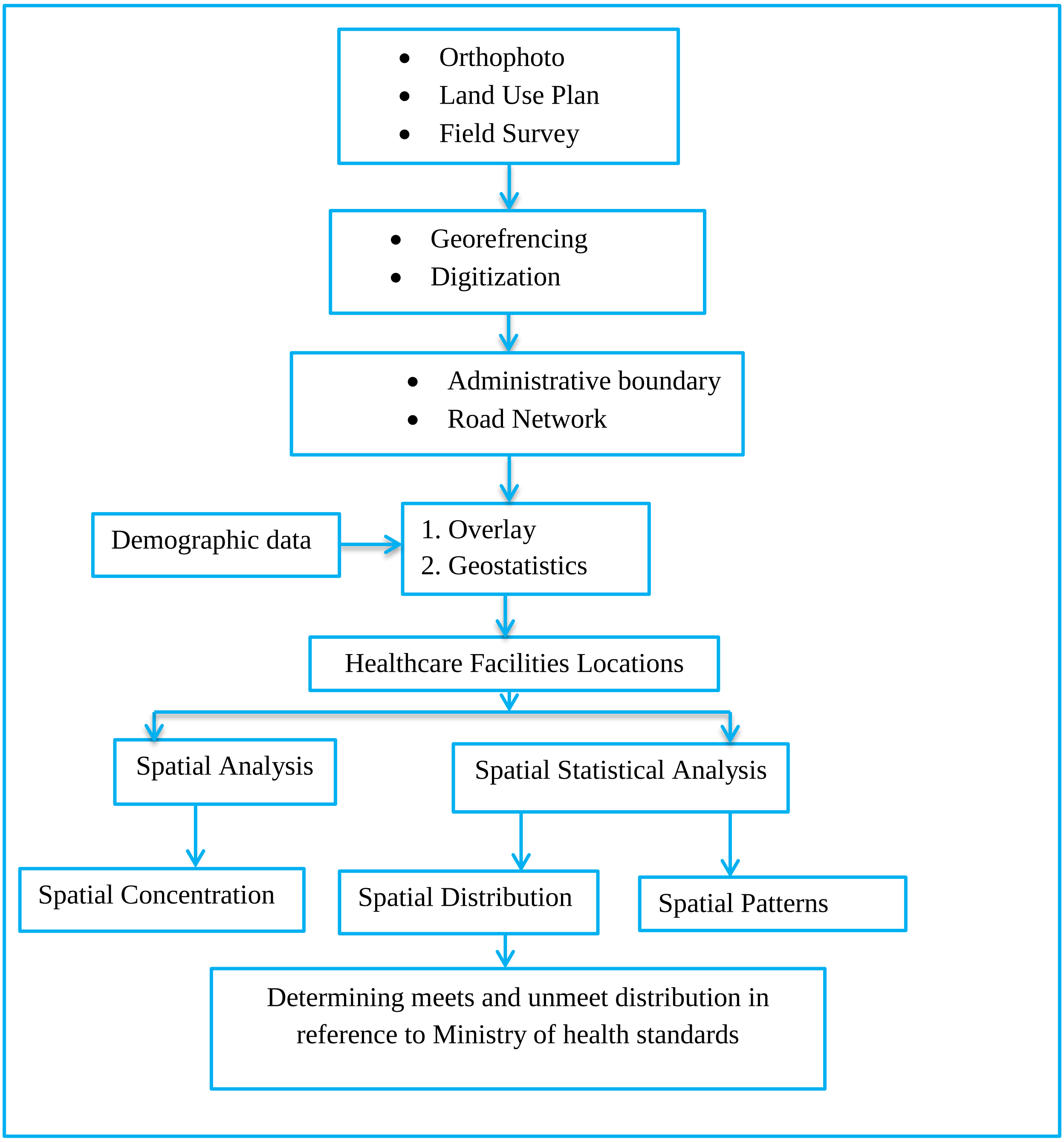


Figure 3.8 Technological Scheme of Spatial distribution,Concentration and Pattern analyses

3.9.4 Spatial Accessibility Analysis

To Analysis spatial accessibility (Guagliardo, 2004) apply the straight line distance between the population point and the location of the health provider. However, travel routes are rarely straight lines in reality. Gravity models, initially developed for land use planning, are also utilized to account for the spatial interaction between healthcare supply and demand (Xia, 2018). The gravity-based accessibility model is essentially the ratio of supply to demand (J. Luo, 2014). A large amount of geo-coded data is required for the locations of both population and health facilities. Sometimes the models also involve great effort in computation and programming (Kim, 2014).

Another development in spatial accessibility modeling is the two–step floating catchment area method (2SFCA) proposed by (W. Luo,2012). The 2SFCA overcomes the restriction of using pre-defined geographical boundaries. However, the limitation of 2SFCA is mainly found in assuming a health provider inside a catchment area is accessible and one outside the catchment area is inaccessible, which tends to be arbitrary, ignoring the possibility of overlapping areas in coverage. Spatial accessibility to health services is primarily dependent on the geographical locations of healthcare providers and the population in need, as well as the travel distance/time between them (Yang, Goerge, and Mullner et al. 2006). Network distance has gained certain popularity in recent literature as a replacement for Euclidean distance and Manhattan distance. It is considered to be a more accurate measurement of real travel distance and time (Poongodi, 2022). However, (Aparicio, 2008) found that Euclidean and Manhattan distances are strongly correlated with network distances. However, in this study, network-based distance was applied rather than Euclidean distance and Manhattan distance.

3.9.5 Service Area by using Network Analysis

A network service area is a region that encompasses all accessible streets (that is, streets that are within specified impedance). Service areas created by network analysts also help evaluate accessibility. Concentric service areas show how accessibility varies with impedance. It is used to identify how many people, how much land, or quantities of anything else within the neighborhood or region. Service area based on time and distance is also helpful to predict the traveling time and traveling distance from demand points to service. In the present study, the service area has been generated from healthcare facility points based on distance and time.

Further, distance based measurement technique was used to analyze the spatial accessibility measure of residents. Because, distance measures are simple to calculate and interpret, requires small amount of data, used as average distance or weighted area distance or distance to the closest activity using road network distance measurement. In this case, the spatial accessibility was analyzed using road network based service area analysis which answers the question what is the likely service area of a facilities based on actual travel distance?‖ In this regard an area was considered accessible if it is enclosed by a polygon generated by specified travel distance from a facility along a road network. Then, number of served population was determined from the product of spatial extent inside service area and population density. Similarly, inaccessible population was computed from spatial extent outside the service area and population density of the area.

Serviced or unserved population $\sum_{I=1}^{23} ai * pd$ .... **(8)**

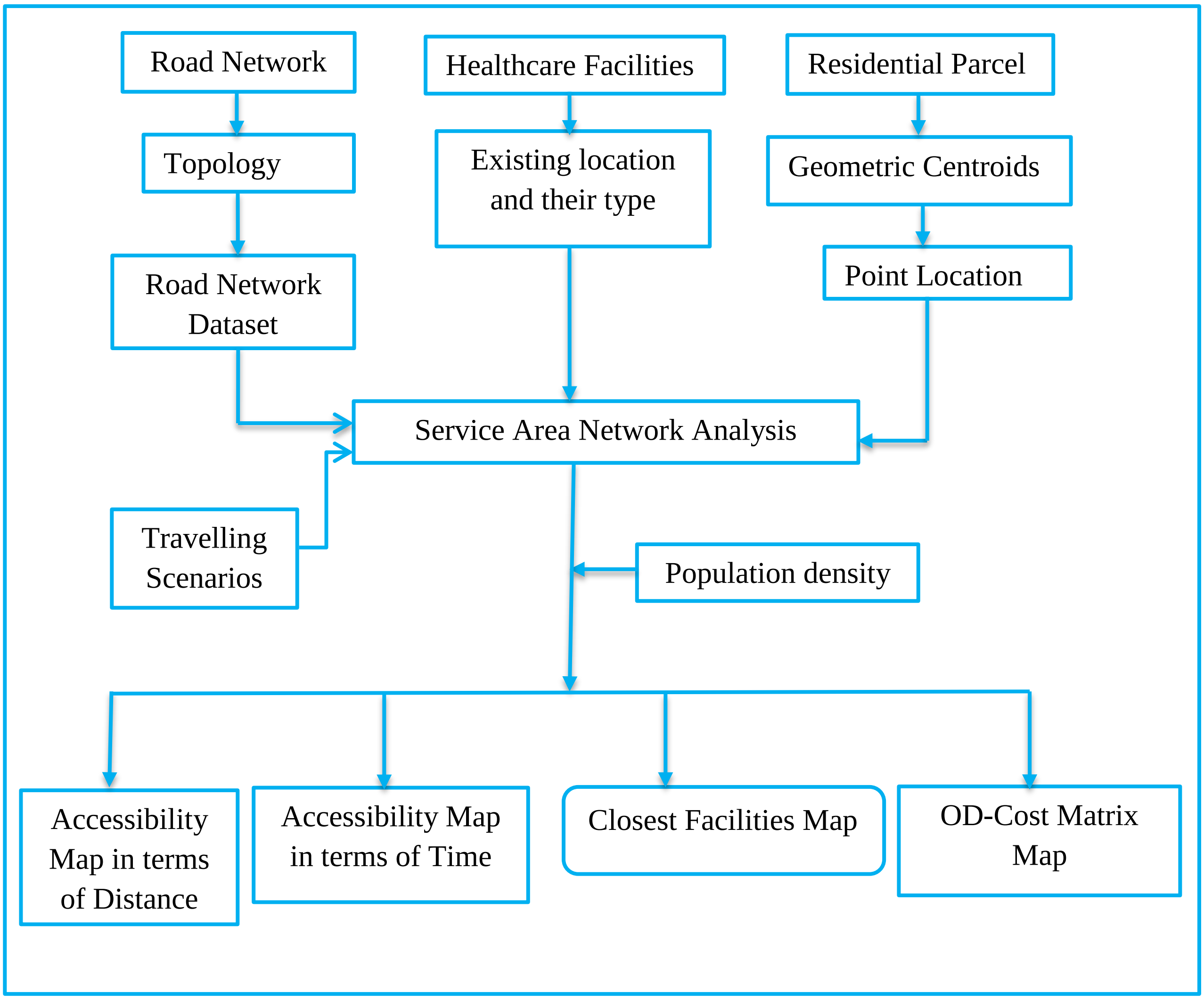


Figure 3.9 Technological schemes for service area-based accessibility analysis

3.10 Methods of Multi-Criteria Analysis (MCA)

In this study, to evaluate and select a suitable site for public healthcare facility using GIS-based multi-criteria analysis the following six main steps were used (Estoque, 2012).

1. Set the goal/ define the problem

2. Determine the criterion (factors/constraints)

3. Standardize the factors/criterion scores

4. Determine the weight of each factor

5. Aggregate the criteria

6. validate/verify the result

1. Set the goal/ define the problem

In this study, the main aim is by using GIS-based Multi-Criteria Analysis (MCA) to evaluate the proposed site and produce a map showing suitable sites for healthcare facilities in Wolaiyta Sodo Town for inaccessible areas.

2. Determine the criterion (factors/constraints)

There were many criteria/factors for healthcare facility site selection. Different literature suggests a variety of factors that may influence healthcare sites. According to the researchers (Halder, Bandyopadhyay, and Banik et al.2020), distance from the existing school, road, industrial, residential, commercial area, stream, transmission line, emergency service, population density, religious institution, manufacturing sites, schools and slope were often used for healthcare site suitability.

3. Standardize the factors/criterion scores

It‘s essential to standardize the data in GIS-based multi-criteria decision-making analysis, to integrate the data measured in different units and mapped in scales of measurement such as ordinal, interval, nominal, and ratio scales (Pereira and Duckstein et al.1993). In this study for factors standardization, all the vector maps of the factors were converted to raster data formats. Then using the Spatial Analyst tool in Arc Map, the raster maps were reclassified. According to (Wale, 2013.).

4. Defining Weights/ Determine the Weight of each factor

Assigning criteria weights for each factor is an important component of GIS-based multi-criteria decision-making analysis. The purpose of weighing is to express the importance or preference of each factor relative to one another factor effect on public healthcare facility site selection. There are several methods available to determine the weight like Analytical Hierarchy Process (AHP), rating, and ranking. For this study the Analytical Hierarchy Process (AHP) method using pairwise comparison matrices was adopted to assign weight for each factor.

Table 3. 8 Criteria for Optimal Site Selection for the Healthcare Facilities.

Factor	Setting
Existing health center	The further away from the existing health center (>=500m), the better
Population Parcel	The nearer away from the residential area, the better
Road	The nearer away from the road (>=100m), the better
Manufacturing sites	The nearer away from the manufacturing and storage (200-500m), the better
Slope	The slope is better, 0-10%
Land use Land cover	The land use considered to analysis cost, availability and use

Source: Prepared by Authors from different literature

3.11 Analytical hierarchy process (AHP)

AHP is first developed by (Wind and Saaty et al.1980) who combines qualitative and quantitative analysis of complex problems of land management with the best alternatives. Analytical hierarchy process (AHP) methodology has been widely used for multi-criteria decision-making regarding land suitability analysis of different land uses. The AHP method determines the weight of importance of different factors influencing land suitability based on pairwise comparisons of the factors considering their relative significance (Kordi and Brandt et al. 2012). In this study, to select a suitable site for healthcare facility development the AHP was carried out in the following three steps:

➢ Pair-wise comparison of criteria

➢ Calculating criterion weights

➢ Calculating consistency ratio (CR)

A. Pair-wise comparison of criteria

Pair-wise comparison of criteria was performed first and results were put into a comparison matrix. A Pairwise comparison matrix was constructed, where each criterion was compared with the other criteria, relative to its importance, on a scale from 1 to 9 which is suggested by (Saaty, 2005).

According to (Wind and Saaty et al.1980), the values in the matrix need to be consistent, which means that if x is compared to y, it receives a score of 9 (extreme significance), y to x should score 1/9 (less significance. In this study, the pairwise comparison matrices were developed by taking into account the information provided by various literature (Abazari, F. Babalhaveaji and Jahangirifard et al. 2012).

B. Calculating criterion weights

The weight of all factors is calculated by normalizing the eigenvector associated with the maximum eigenvalue of the (reciprocal) ratio matrix. Manually the computation of the criterion weights involves the following operations: (a) summing the values in each column of the pairwise comparison matrix; (b) dividing each element in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix and (c) computing the average of the elements in each row of the normalized matrix that is, dividing the sum of normalized scores for each row by the number of criteria. In this study, the computation of criterion weights was calculated by using IDRISI Selva software.

C. Calculating consistency ratio (CR)

After the pair-wise comparison was filled and the weight of the factors was determined, a consistency ratio (CR) was calculated to identify inconsistencies and develop the best-fit weights in the complete pair-wise comparison matrix. A consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008). But if a consistency ratio is greater than 0.1, then there are inconsistencies in the evaluation process and the AHP method may not yield a meaningful result (Saaty, 2007). A consistency ratio was calculated for the matrix to verify the degree of credibility of the relative weights, by using the following formula:

$$\mathbf{CR} = \frac{CI}{RI} \quad \textbf{(9)}$$

Where CR=Consistency ratio, CI = referred to as consistency index, RI = is the random consistency index whose value depends on the number (n) of factors. The consistency index (CI) was calculated by the following formula:

$$\mathbf{CI} = \frac{\lambda \max}{n-1} \quad \textbf{(10)}$$

Where λ max is the principal Eigenvalue; n is the number of factors. λmax = Σ of the products between each element of the priority vector and column totals.

5. Aggregate the criteria

Step five was to aggregate the criteria using a weighted linear combination (WLC) and apply it in the ArcGIS raster calculator.

3.12 Weighted overlay analysis

After the criteria maps and weights have been developed and established, a decision rule of multi-criteria analysis was used. There are three common decision rules in multi-criteria analysis namely weighted linear overlay, Boolean overlay, and ordered averaging (Jiang and Eastman 2000). In this study, the weighted linear combination (WLC) technique was applied to aggregate the standardized layers. In this technique, factors or parameters (Xi) are multiplied by the weight of the parameters (WI) to get composited weights and then summed. This can be done by using the following formula to derive the intended map (i.e. Public healthcare site suitability map for Wolaiyta Sodo town).

$$\mathbf{S} = \sum_{1}^{n}(\boldsymbol{WiXi}) \quad \textbf{(11)}$$

3.13 Research Design

The conceptual structure or the design of the research project that the researcher followed to conduct the research became an important issue to be clearly defined to visualize the whole image of the work. Both Quantitative and Qualitative research approaches are implemented to produce the spired information or result which when combined known as the Mixed Approach. Even though the qualitative side has more weightage to the final result of the analysis, it is not manageable without the involvement of the quantitative side. The inspiring purpose of the research is to see that healthcare facilities in Wolaiyta Sodo Town are fully accessible by the demand population of the Town at a minimum distance and time.

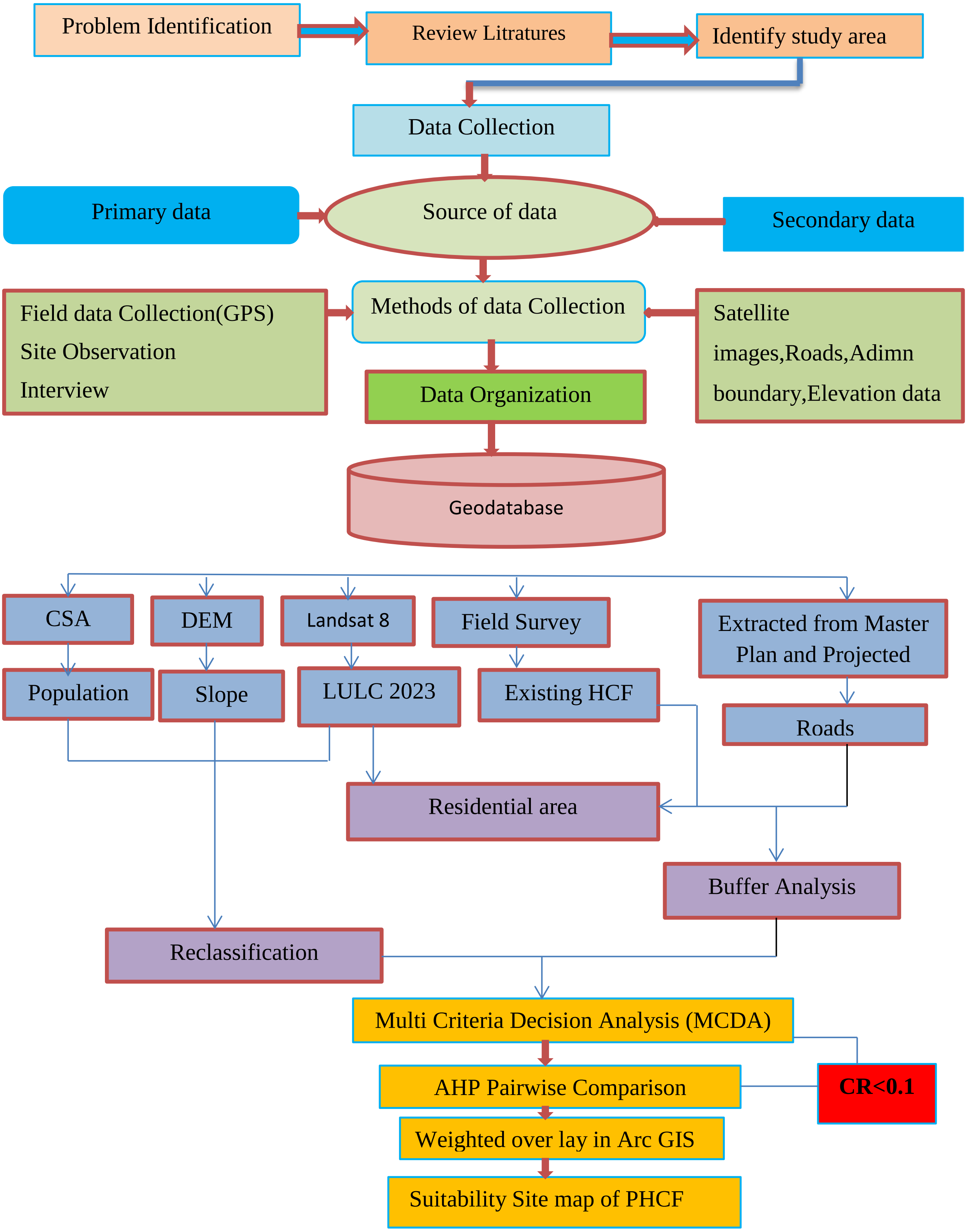


Figure 3.10 Methodological work flow

CHAPTER IV: RESULTS & DISCUSSION

This chapter attempted to deal with the data to answer the previously stated research questions starting from estimated assumptions up to the most reliable solutions that even stakeholders can apply to the action. Relevant data analyses are performed using a predefined methodology and sequential spatial analysis approaches. Descriptions of the discussed results in the form of information are briefly arranged. Discussions are provided to meet the purpose of the study and objectives set briefly at the beginning of the study. Finally, the intended and refined greatest output of the research which is the accessibility of public healthcare facilities are analyzed, and the new suitable sites are selected.

4.1 Land Use Land Cover Classes of Wolaiyta Sodo Town

A land use classification is a classification providing information on land cover, and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on and potential or alternative uses of land. There is several land use types are recognized in irregularly mixed appearance with one another throughout the whole study area. According to information from Sodo town land Administrative, there is about much class number of land use types identified in town such built up, forest land, agricultural land, vegetation cover and bare land.

4.2 Accuracy assessment of land use land covers classification

Accuracy assessment is the final step in the analysis of remote sensing data which helps us to verify how accurate our results are. It is carried out once the interpretation/classification has been completed. The confusion matrix/error matrix has numbers as the number of samples. Any particular quantity is arranged in rows and columns i.e. square matrix, where columns represent the referencing data while row represents the classification data. The overall accuracy for the LULC image is defined as the total correct pixels (major diagonal‘s sum) divided by the total number of pixels in the provided matrix which is 89.211 %(see table 4.1) below. In addition, the overall kappa coefficient for the image was = 0.887816 i.e. 88.7816% better agreement than by chance alone respectively. Kappa values are characterized as < 0 as indicative of no agreements and 0 to 0.2 as slight, 0.2 to 0.41 as fair, 0.41 to 0.60 as moderate, 0.60 to 0.80 as substantial, and 0.81–1.0 as almost 40 perfect agreements. Therefore, the overall classification accuracy of the image yielded a Kappa statistic of 88.7816% (Table 4.1) for the 2022 image. This implies that the image classification accuracy was almost perfect agreement.

Table 4.1 Classification accuracy of Sodo Town 2023 Satellite image

REFERENCE DATA (2023)								
CLASSIFIED DATA (2023)	LULC	Built up	Bare land	Forest	Vegetation cover	Farm Land	Total points	U.A (100%)
	Built up	41	1	1	2	2	47	87.24
	Bare land	0	43	0	0	5	48	89.58
	Forest	0	0	44	2	0	46	95.65
	Vegetation cover	2	5	0	45	1	53	84.90
	Farm Land	1	2	0	2	42	47	89.36
	Total Points	44	51	45	51	50	241	
	P.A(100%)	93.18	84.32	97.70	88.24	84.10		

Overall Accuracy = 215/ 241 = 0.892117

Overall Accuracy percentage =0.892117 * 100 = 89.2117%

Kappa Statistics K ^ = 0.887816 * 100 = 88.7816

User Accuracy (Row)	**Produce Accuracy (Diagonal)**
Built up = (41/47) * 100 = 87.234%	Built up = (41/44) * 100 = 93.182%
Bare land = (43/48)*100 = 89.583%	Bare land = (43/51)*100 = 84.313%
Forest/shrub land = (44/46)*100 = 95.652%	Forest/shrub land = (44/45)*100 = 97.777%
Vegetation cover = (45/53)*100 = 84.906%	Vegetation cover = (45/51)*100 = 88.235%
Farm Land = (42/47) * 100 = 89.362%	Farm Land = (42/50) * 100 = 84.00%

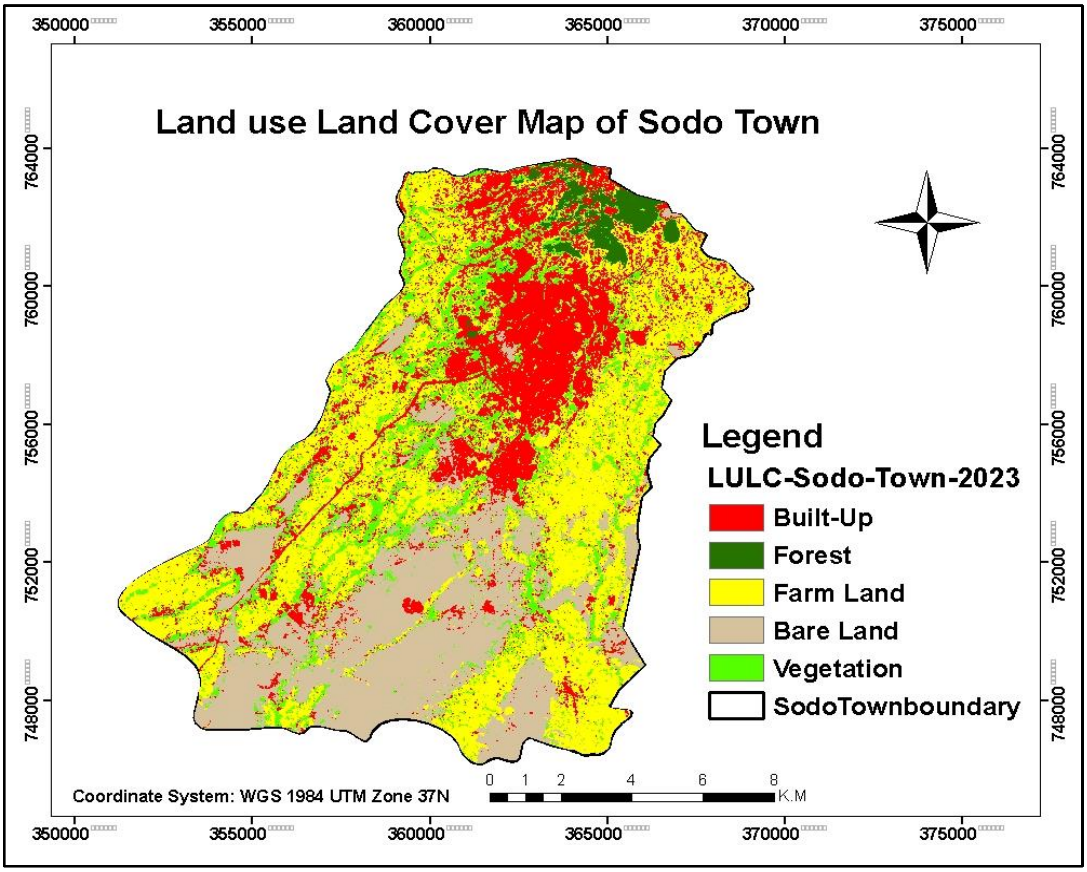


Figure 4.1 LULC map of the study area in 2022

Table 4.2 Area Covered by Each Land Use Land Cover

No	Land use Land cover type	Area in (Sq.km)	Area in (%)
1	Built up land	13.1770	11.22
2	Forest cover	20.3344	17.32
3	Farm land	41.2290	35.10
4	Vegetation	8.2575	7.04
5	Open space or Bare land	31.5530	29.32
Total coverage		114.5	100

4.3 Spatial Distribution of Healthcare Facilities in the Study Area

Overlay analysis was carried out on the healthcare locations and kebeles administrative boundary to show the distribution and relationship between them. According to the Wolaiyta Zone Health Bureau the estimated population of 2015, the population of Sodo Town was estimated at 296,246. The Sodo Town administrative body establish a new sub-city for effective service delivery for the people in 2015 the Town has three sub-city administrative that includes 23 kebele and this study used this new current kebele level analysis. Based on the area calculation kebele 19 has the highest area with a total of 8.69 sq. km the second is Kebele 13 having 7.73 sq. km, followed by Kebele 2, Kebele 11and kebele 21 is the least area coverage of 2.21sq.km.The number of existing Public Healthcare facilities in the study area by each kebele's is presented in Table 4.4 below. The ratio and the comparison between the number of healthcare facilities and the population results in disparity from the standard only a limited number of institutions meet the standard, and ten kebeles have no health facilities (kebele 1, 5,10,14,15,17,18,19 and 23). Kebele 3 and 12 have two public healthcares facilities. There is one General hospital in kebele 4 and one primary private specialized hospital in each kebele 6 and 12 which can provide services at town levels following the standards set by the Ministry of Health (MOHS), it was observed that there is inadequacy in the spatial distribution of the primary healthcare facilities, specifically in eleven kebeles. The results of the ratio of Healthcare to each kebele in the study area are presented in Table 4.3 below.

Table 4.3 The Ratio of Existing Public Healthcare Facilities

No	Kebele	Kebele extent (sq. km)	Projected Population (2015)	No. of HCF	Ratio	Remark
1	Waja Kero	5.338187	10, 692	--	---	No Healthcare found!
2	Dalibo Wogane	6.272910	29, 941	1	1:29,941	Meet with the MOHS
3	Kidane Mihret	6.2041628	22,797	2	1:11,399	Meet with the MOHS
4	Gido	4.6692390	25,565	2	1:12,783	Meet with the MOHS
5	Wareza Shoya	5.9336370	13,256	----	-----	No Healthcare found!
6	Hibret	6.1040784	22,692	1	1:22,692	Meet with the MOHS
7	Selam	3.5369965	11, 878	-----	1:11,878	Meet with the MOHS
8	Wadu	5.2040718	26, 102	3	1:8701	Meet with the MOHS
9	Dil Bettgil	26, 454	26, 102	1	1:26,102	Meet with the MOHS
10	Fana	6.9518086	17, 721	----	-----	No Healthcare found!

11	Ofa sere	4.934730	14,921	1	1:14,921	Meet with the MOHS
12	Kera	5.3654255	12,578	2	1:6289	Meet with the MOHS
13	Wareza Gerera	7.728459	6957	1	1:6957	Meet with the MOHS
14	Haba Gerera	5.1661228	13, 380	----	-----	No Healthcare found!
15	Gututo Larena	4.1679003	5569	----	-----	No Healthcare found!
16	Humbo Larena	7.4433318	26,231	1	1:26,231	Meet with the MOHS
17	Shchora Osa	2.8568256	5291	----	-----	No Healthcare found!
18	Ansome Gemba	2.1199564	6941	-----	------	No Healthcare found!
19	Ofa Gandaba	8.69487	13,380	-----	-----	No Healthcare found!
20	Damota	3.9575566	15, 860	1	1:15,860	Meet with the MOHS
21	Merkato	2.2176755	31,596	1	1:31,596	Meet with MOHS
22	Gola	3.0735526	13,784	1	1:13,784	Meet with the MOHS
23	Bosa Kacha	5.5760426	6489	----	-----	No Healthcare found!

As shown in table 4.3 the first problem is that most kebele such as kebele 1, 5,7, 10,14,15,17,18,19, and 23 totally ten kebeles in the town have no healthcare facilities in their kebele completely this kebele population in the town can travel greater than 2 km to get the service from other kebeles their sum of the populations in those ten kebeles are 91,593 . Only eight kebeles from 23 such as kebele 3, 6,11,12,13,15,20, and 22 meet the requirements. For the residents who live in those inaccessible kebeles to get access of medical treatment from a healthcare facilities, they would be forced to travel to neighboring kebele that may be more than 2 km or longer.

4.4 Spatial Concentration of Healthcare Facilities in the Stud Area

The computed value of spatial concentration measured by location quotient (LQ) using Eq. 1 is shown in Table 4.3 alongside the number of healthcare facilities and population in respective Kebeles. Overall, at the town scale level the general proportion of healthcare facilities to the total population is about (1:30,272) which is acceptable as compared to the standard set by the Ministry of Health (1:40,000) for healthcare facilities in urban areas in terms of population but due to the problems of concentration this healthcare facility in most kebele's in the town not meet the standard either exceeds from the standards or below from the standard shown in table 4.3 below.

Table 4.4 Spatial concentration of healthcare facility in Wolaiyta Sodo Town 2023

No	Kebele	Pop. total	Number of Healthcare facilities in kebele level	Location Quotient (LQ)
1	Waja Kero	10, 692	-	-
2	Dalibo Wogane	29, 941	1	0.54
3	Kidane Mihret	22,797	2	2.33
4	Gido	25,565	2	1,25
5	Wareza Shoya	13,256	-	-
6	Hibret	22,692	1	1.18
7	Selam	11, 878	-	-
8	Wadu	26, 102	3	3.07
9	Dil Betgil	26, 454	1	0.57
10	Fana	17, 721	-	-
11	Ofa sere	14,921	1	1.80
12	Kera	12,578	2	2.40
13	Wareza Gerera	16,557	1	1.80
14	Haba Gerera	13, 380	-	-
15	Gututo Larena	5,569	-	-
16	Humbo Larena	26,231	1	1.01
17	Shchora Osa	5,291	-	-
18	Ansome Gemba	6,941	-	-
19	Ofa Gandaba	13,380	-	-
20	Damota	15, 860	1	1.68
21	Merkato	31,596	1	0.55
22	Gola	13,784	1	1.94
23	Bosa Kacha	6,489	-	-
	Total	296,246	17	

The computed Location Quotient (LQ) demonstrates that the concentration of the Healthcare facility in each Kebele possesses different ranges (under normal concentration, self-sufficient, above normal concentration) the LQ value greater than 1 kebele indicates above normal concentration. From the above study area kebeles maximum value LQ is (3.07) in Wadu Kebele indicates there is the highest concentration. The next is the Kera kebele which has a value of 2.40 and the value of LQ less than 1 kebeles indicates under normal concentration and the kebele which has no health centers indicates there is the lowest concentration. This indicates that the level of concentration of healthcare facilities varies quite significantly across kebeles in the town and leads to believe that considerable disparity exists among the kebeles in terms of concentration.

Further, to investigate the relationship between population and the number of healthcare facilities, the Pearson Product Moment Correlation Coefficient technique was applied to the data. The result depicted in Fig. 4.2 is shown below.

Table 4.3 Correlations between Healthcare Facilities and Population Total

		pop_total	Health-Center
	Pearson Correlation	1	.534**
Pop_total	Sig. (2-tailed)		.009
	N	23	23
	Pearson Correlation	.534**	1
Healthcare facilities	Sig. (2-tailed)	.001	
	N	23	23

. Correlation is significant at the 0.05 level (2-tailed)

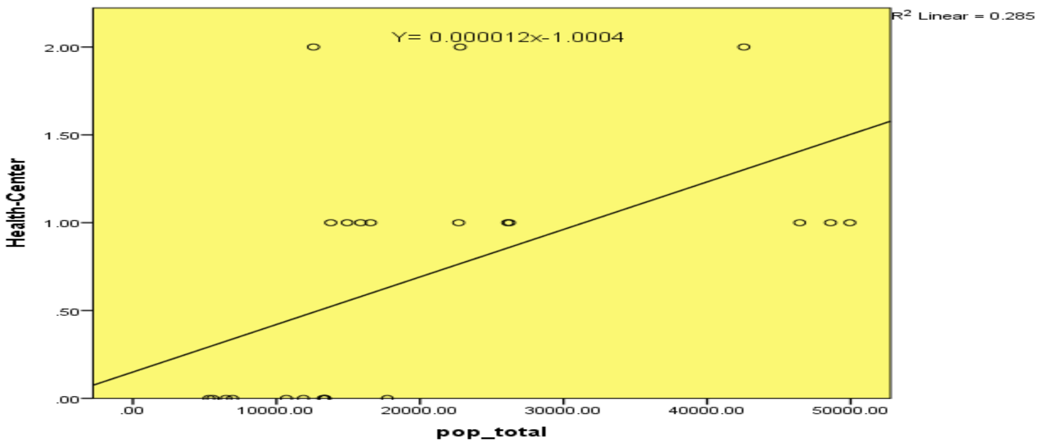


Figure 4.2 Correlation between Population and Healthcare Facilities

From the above correlation between the healthcare facilities and population total in each kebele, there is positive relationship between them. The value indicated line of best fit is linear, while the coefficient of correlation (r) is 0.534 significant at 0.05 (95%) confidential significant level. The coefficient of determination (R-square) value of 0.285 indicates that about 28.5% of the variance in healthcare facility less influenced by the population numbers of the respective kebeles. From this correlation result in the study area the existing healthcare facility distribution does not highly depend upon the population total in respective each kebeles because the total number population is the first factor to locate the healthcare facilities to demand location. Depending on this result the existing healthcare facility concentration does not more considered the population distribution.

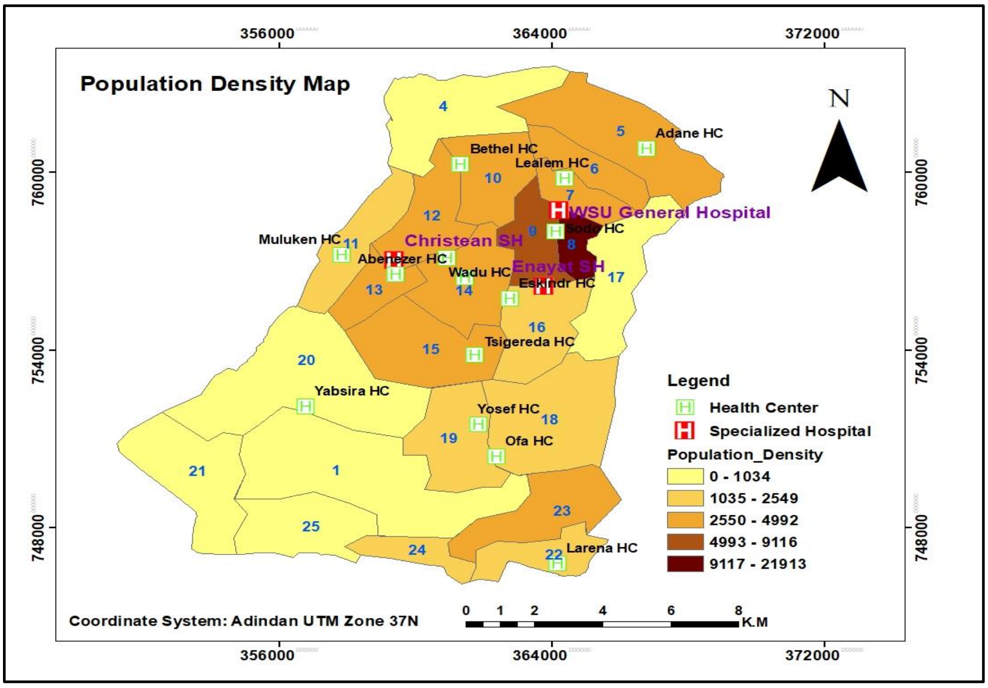


Figure 4.3 Population Density & HCF Distribution of Sodo Town

4.5 Healthcare Facilities Distribution Pattern in the Study Area

4.5.1 Mean Center

The simplest way to describe a geographic distribution is the mean center, which is the average x- and y-coordinate of all the features in the study area. It's valuable for following changes in the conveyance or for looking at the circulations of various kinds of elements. The mean community can likewise be numerically addressed where the coordinates for features are xi and yi, and n is the number of features. It was found that the mean center of the Public healthcare facility in the study area was displayed on the map (see Figure 4.4).

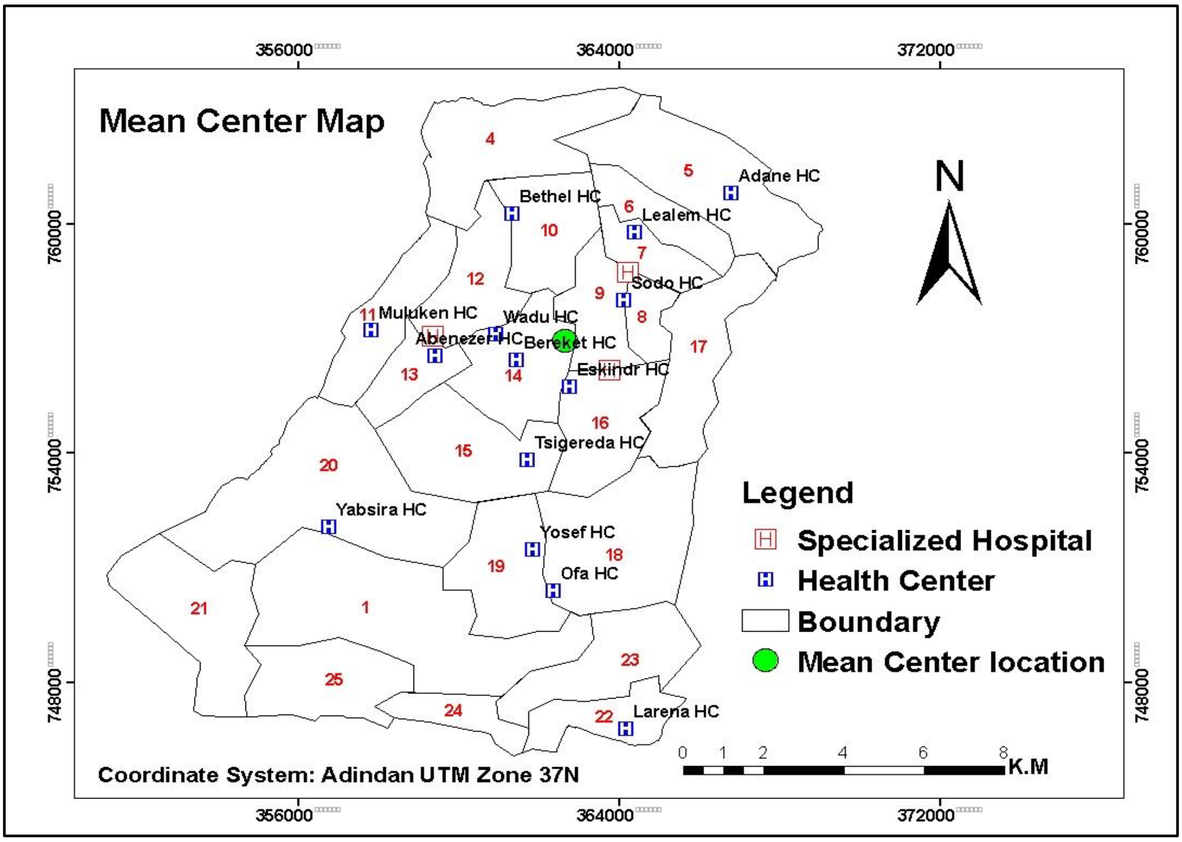


Figure 4.4 Mean center Map of Public Health facilities of W/Sodo Town

4.5.2 Directional Distribution patterns

By drawing highlights on a map, calculating the standard deviational ellipse, and clarifying the directional growth of the healthcare facility in Sodo Town, GIS analysis can also provide a sense of direction. Using either the region of the feature or the region impacted by an attribute value related to the features, the tool analyzes and clarifies the trend. Weighted standard deviation is the name given to the latter. The outcome could assist specialists and organizers with having a goal comprehension of the current focus and appropriation of understudies and administrations in different regions of the towns for better direction and administrations improvement. Estimating the pattern for a bunch of focuses or regions is to work out the standard distance independently in the x-and y-bearings. To summarize the spatial characteristics of geographic features, including central tendency, dispersion, and directional trends Directional Distribution of healthcare facilities was done. The ellipses are centered on the mean center. This tool calculates directionality, centrality, and dispersion. The created ellipse is referred to as the standard deviational ellipse and allows seeing if the distribution of features is elongated and hence has a particular orientation from the result of the direction of the health facility distribution there is much of healthcare facility compacted in central and northeastern parts of the town has highest distribution.

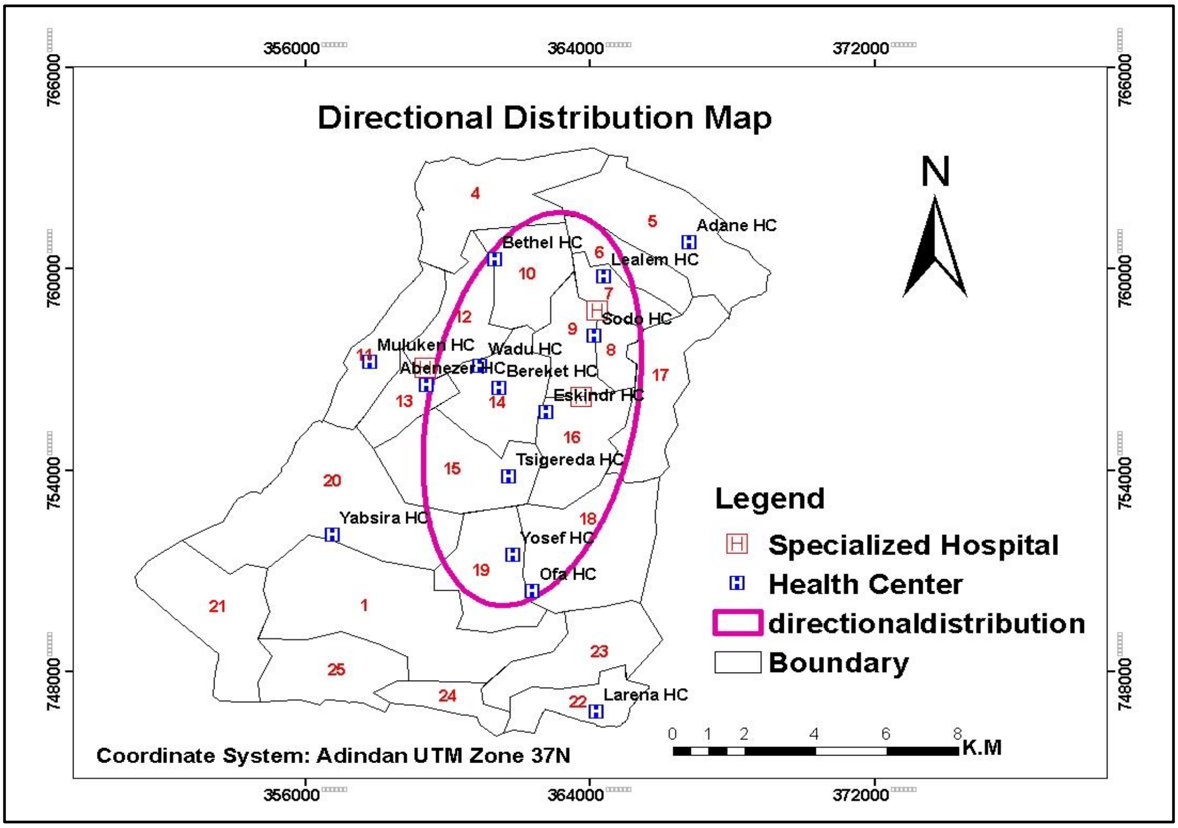


Figure 4.5 Directional Distribution Map of the healthcare facilities W/Sodo Town

4.5.4 Kernel Density

The kernel density tool computes the density of elements in a neighborhood around those highlights. It can be used to calculate both points and lines. Each point is conceptually covered by a surface that curves smoothly. The surface value decreases as the distance from the point increases, reaching its highest value near the point. As a consequence of this, the outcome demonstrates that the result was high at each health center, with a maximum value of 0.383566 and 0 values, such as in kebele1, 13, 14, and 18. Conceptually, a surface with a smooth curve is fitted over each point. The surface worth is most elevated at the area of the point and decreases with expanding distance from the point, arriving at zero at the Hunt range distance from the point. The thickness at each result raster cell was determined by adding the upsides of all the piece surfaces where they overlay the raster cell focus. The quartic kernel function outlined in Silverman (1986, p. 76, equation 4.5)

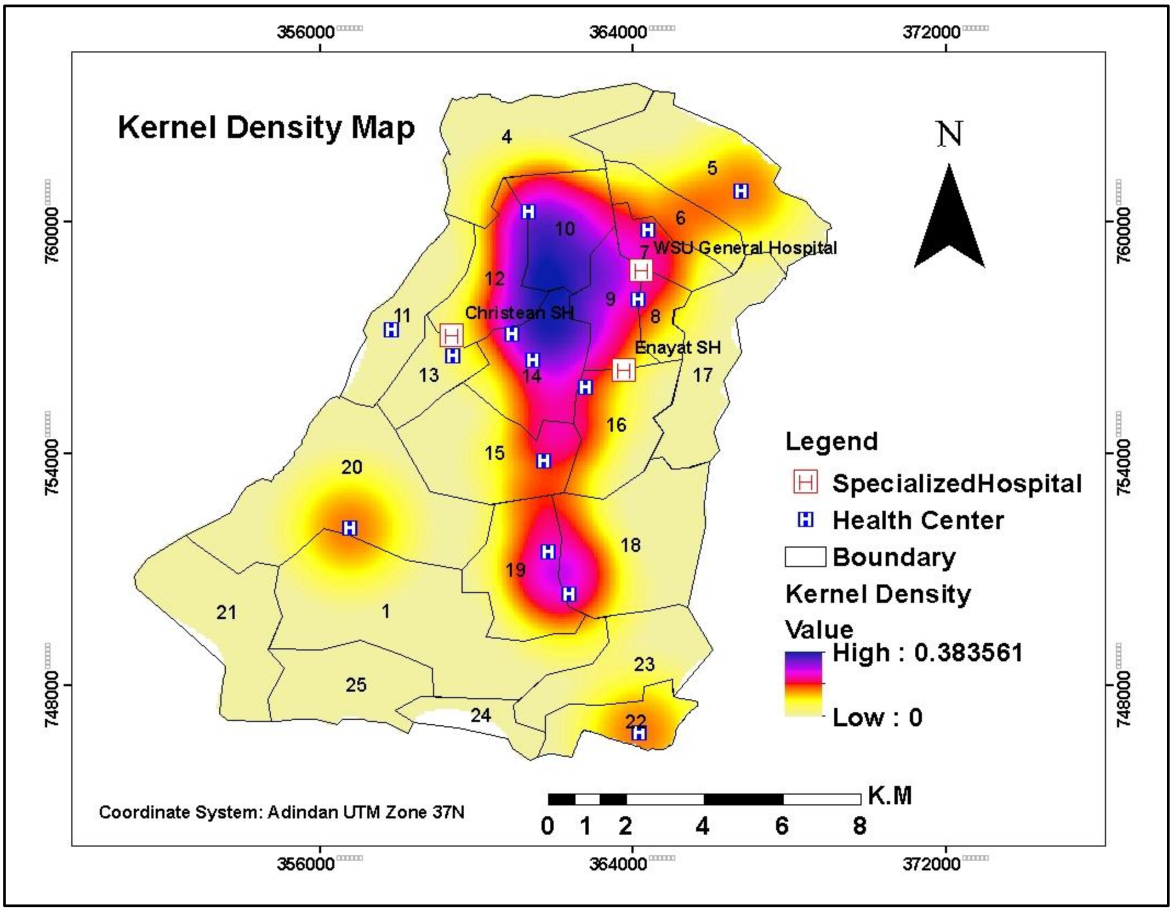


Figure 4.6 kernel Density Map of W/Sodo Town

4.5.5 Nearest Neighbor Analysis (NNA)

The nearest neighbor analysis (NNA) is a descriptive statistic that shows a pattern of locating features by comparing graphically the observed nearest neighbor distance. That is, it describes a phenomenon based on its distance from another phenomenon in space. The nearest neighbor analysis does not only examine the distance between points, but it also examines the closest point to it (Fotheringham and Woulder et al.1999). The nearest neighbor index measures the degree of spatial dispersion of features over distance. Its value ranges between 0 to 2.15 and it shows if a settlement is clustered, random, or regular.

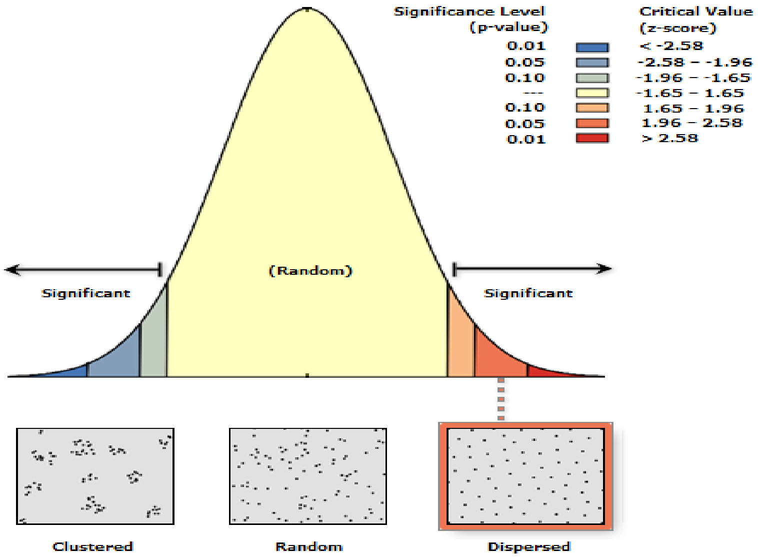


Figure 4.7 Average NNR Summary1

Average Nearest Neighbor Summary

Observed Mean Distance:	1965.2208 Meters
Expected Mean Distance:	1450.0643 Meters
Nearest Neighbor Ratio:	1.355265
z-score:	2.543002
p-value:	0.010990

Dataset Information

Input Feature Class:	HealthCenter
Distance Method:	EUCLIDEAN
Study Area:	117750446.649349

Figure 4.8 Average NNR Summary2

The result of the analysis shows that Rn 1.355265 (Rn >1) and also values of Z-score (+2.54300230788) is less than the critical value +2.58 and P-value (0.01099) which is greater than 0.01 reveal that the observed distribution pattern is more random distribution at 95% confidence level.

4.6 The Spatial Accessibility Level of Public Healthcare Facilities to Residents

The spatial accessibility levels of public healthcare facilities to residents in study area in terms of distance and time determined by using service area analysis by using road network

4.6.1 Road Network Map in the Study Area

Generating the road network map is the primary part of the analysis for service area coverage in terms of distance and time, to produce the closest facility and OD Cost Matrix analysis to determine the level of accessibility in the study area shown in the figure 4.9 below. .

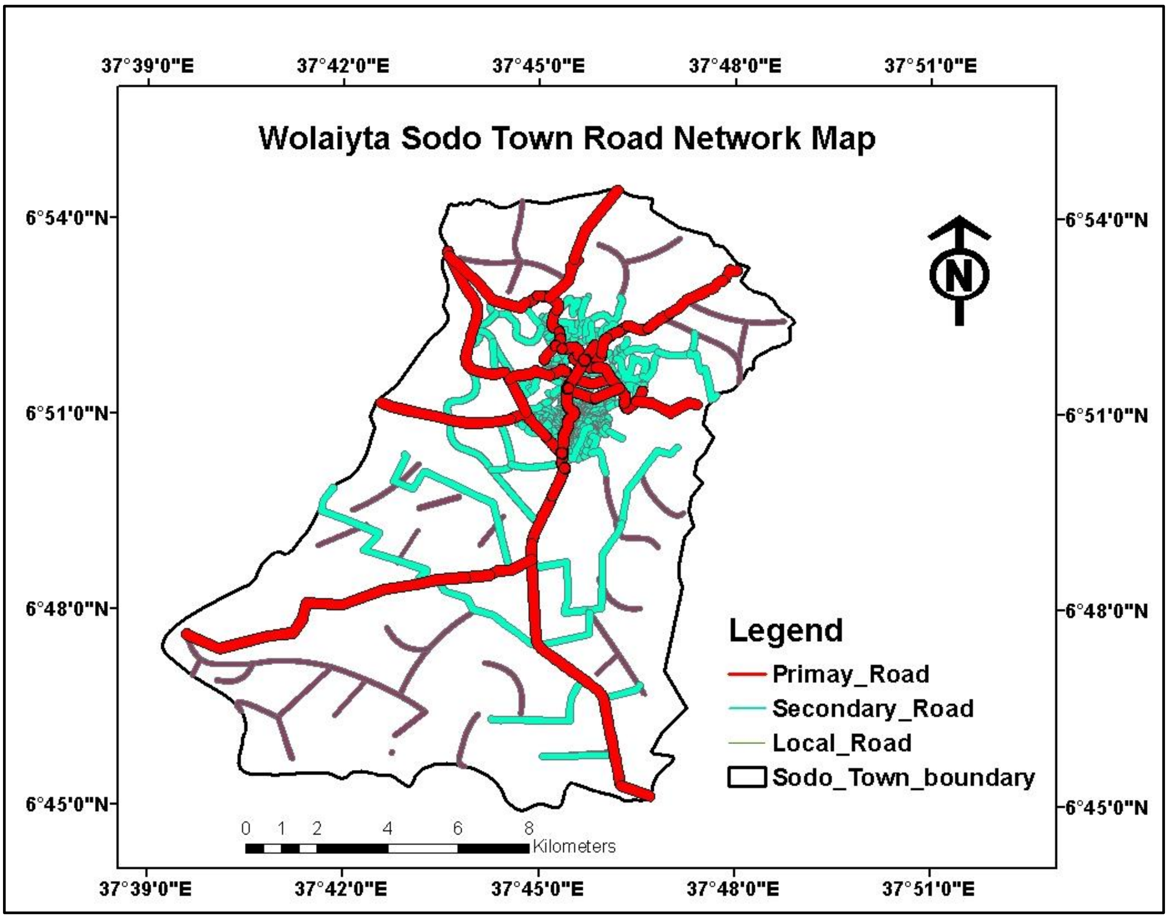


Figure 4.9 Road network map of the Sodo Town

This stage works on readjustments and changes in the road network data and the land use of the study area. Therefore it was obligatory to change from the original file format to the format type supposed to use. ArcGIS Network Analyst uses the road network to find its analysis result. But Sodo Town's local road network data were available in only area shapefiles that bound the areas covered by it. Hence primarily, for secondary and tertiary roads the centerlines of this network data are traced from the existing and digitized data using editing tools in ArcMap and further modifications and additional road network parts are also added. After all editing activities are finished Sodo Road network Topology (i.e. geodatabase Topology) is built. The road network analysis function was applied to compute the service area, closest facilities, and OD-Cost Matrix analysis based on distance and time interval. According to the ERA technical standards (ERA,2018) travel speeds are set according to the quality of the road, i.e. 60, 40,30 and 5 km/h for primary, secondary, local and walking speeds used in this study respectively. To do this the road network data has been prepared based on the study area boundary extent. Both the geometric and attribute information was checked, and to fix some geometrical errors topology rules were applied for the vector-based road network data and it was corrected. Next to this, it was tested on the functionality of road network analysis such as setting the proper speed limit attribute information based on the standard. Then to compute the travel time the network analysis was performed by accessing the data set from the confirmed geodatabase created.

4.6.2 Distance-Based Service Area Spatial Accessibility Analysis

In this phase of generating service areas for the facilities, the cost attribute employed is distance. Scenarios are laid made for the distance-based analysis of the above by taking the nationally recommended distance of 2 km into consideration. Based on this, 0.5 km for the first, 1.5km for the second, 2km for the third, 3.5km for the fourth, and 5km for the fifth break values are selected to generate the results

Based on the results it‘s varying according to the minimum requirement set by World Health Organization (WHO,2017). Within the range of 2 km distance, it is the smallest area recorded in all facilities, but more than 2 km to 5 km the area coverage is wider. For instance, in the range of 3.5 km to 5 km distance, The results show that it is the widest of all ranges specified on the map e.g. Facilities such as the Otona General Hospital is over 13.3 km sq. which was wide in the range of 3.5 km to 5 km. Enayat primary hospital was found to be 12.4 sq. km from the 3.5 km to 5 km range, Sodo Christean primary hospital was found to be 11.4 sq. km, Wadu Health Center is 10.9 sq. km wide, and Abenezer 10.4 sq. km wide. The health care facilities within the study area are only accessible for a limited number of populations by car and by walking according to criteria. Using the road network analysis function travel distances to the nearest health care facilities and service area has been calculated for each public Health Facilities. Within the specific healthcare facilities and their surrounding localities, the green, and blue colors of the area which have greater than a 5,000-meter distance which is not included in the break value indicate low accessibility as the results displayed on the map (See Figure 4.10). The total area served by the public health facilities within 2 km is 94.1 km^2, from 2 km to 3.5 km is 89.7 km^2 and from 3.5 km to 5 km is 136.9 km^2, specifically for distance interval of more than 2 km the total area would be 226.6 km². Therefore additional health care centers need to be provided in the area outside the 2km which is green, blue color and also outside 5km coverage area.

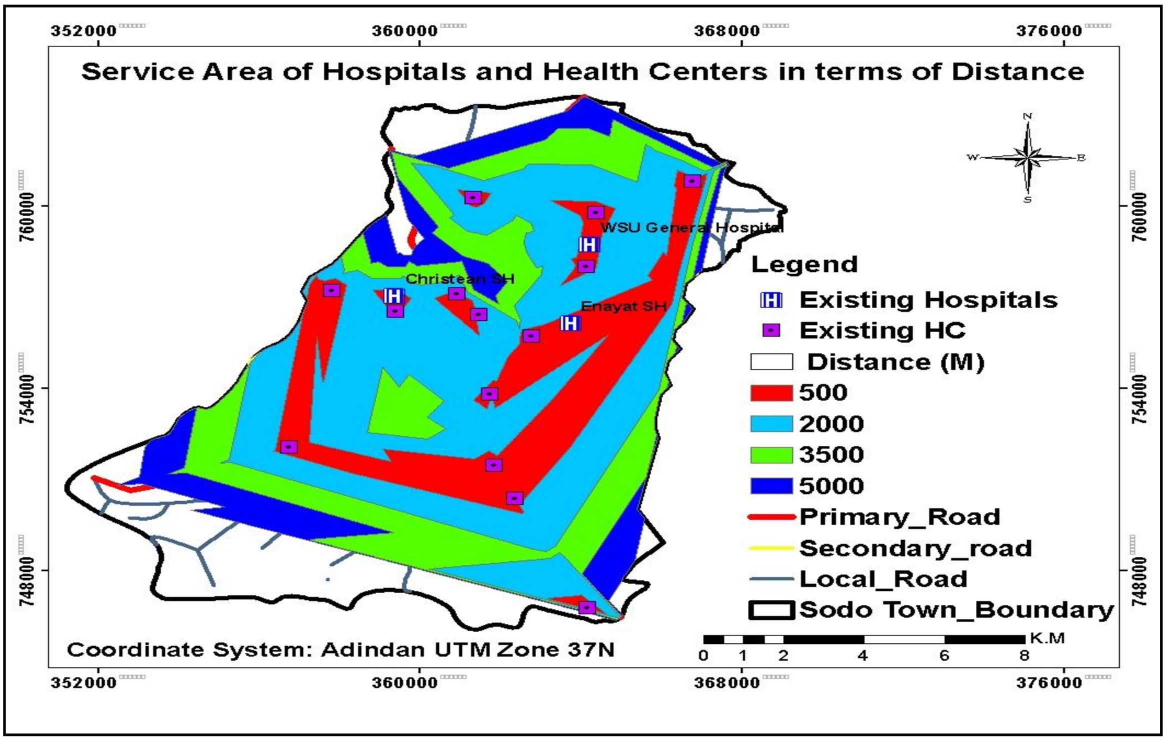


Figure 4.10 Distance Based Service Map of W/Sodo Town

Table 4.5 Health facilities and their service area coverage in distance

No	Health Center	Type	Service Distance Range			
			From 3.5-5Km distance	From 2-3.5Km distance	From 0.5-2Km distance	From 0-0.5Km distance
1	Yosef	Health Center	6.8 Sq.km	4.5 Sq.km	1.5 Sq.km	1.5Sq.km
2	Yabsira	Health Center	6.6Sq.km	6.7 Sq.km	1.3 Sq.km	1.8 Sq.km
3	Tsigereda	Health Center	4.5Sq.km	8.3 Sq.km	1.5 Sq.km	2.7 Sq.km
4	Enayat	PrimaryHospital	12.4Sq.km	5.8Sq.km	2.2 Sq.km	3.6 Sq.km
5	Bereket	Health Center	10.4Sq.km	6.4 Sq.km	1.7 Sq.km	2.3 Sq.km
6	Sodo	Health Center	4.4Sq.km	6.6Sq.km	4.2 Sq.km	1.8 Sq.km
7	Ofa	Health Center	8.3Sq.km	3.8Sq.km	5.2Sq.km	2.6Sq.km
8	Wadu	Health Center	10.9Sq.km	4.4Sq.km	3.4Sq.km	3.2Sq.km
9	OtonaUniversty	GeneralHospital	13.3Sq.km	4.2Sq.km	1.7Sq.Km	3.6Sq.km
10	Adane	Health Center	5.7Sq.km	6.4Sq.km	2.4Sq.km	2.7Sq.km
11	Muluken	Health Center	8.6Sq.km	5.9Sq.km	4.3Sq.km	1.8Sq.km
12	Eskindr	Health Center	7.4Sq.km	2.6Sq.km	1.8Sq.km	3.1Sq.km
13	Abenezer	Health Center	10.4Sq.km	3.4Sq.km	3.6Sq.km	2.6Sq.km
14	Larena	Health Center	7.3Sq.km	5.9Sq.km	2.6Sq.km	2.5Sq.km
15	Sodo Chirstean	Primary Hospital	11.4Sq.km	1.8Sq.km	3.9Sq.km	2.6Sq.km
16	Lealem	Health Center	5.5Sq.km	3.4Sq.km	3.5Sq.km	1.7Sq.km
17	Bethel	Health Center	4.5Sq.km	9.6Sq.km	6.8Sq.km	2.4Sq.km
Total			136.9Sq.km	89.7Sq.km	51.6Sq.km	42.5Sq.km

From the above service area table for each Healthcare center and Hospital in the town, it includes a totally 14 health centers,2 specialized hospitals and 1 general hospital are available in the town their service accessibility in terms of distance shows the mostly the town has higher coverage in 3.5-5sq.km 136.9 sq.km (42.7%) next by 2-3.5 sq.km that is 89.7 sq.km (28%) then 0.5-2km is 51.6sq.km (16%) and lastly by 0-0.5km distance that is 42.5 Sq.km (13.3) in the percentage. The total area covered by some facility due to their close distribution in one kebele most area are overlapped which mean some people have a chance to get the service from different healthcare facilities. However, most peoples have inaccessible service accessibility therefore it needs the additional health at least to fulfill the (WHO,2017) minimum standard that to make all community peoples equally accessible.

The charts in Figure 4.11 below show the service accessibility in distance range by graphically detailed observation.

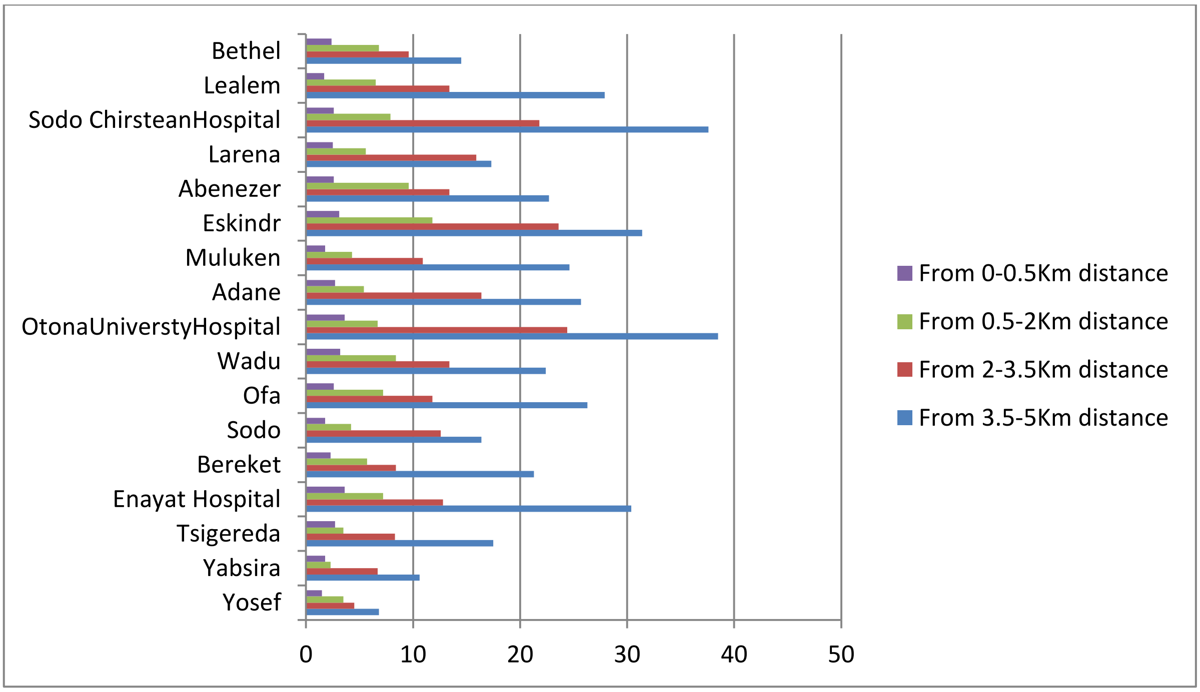


Figure 4.11 Health facilities and their Service area Coverage in terms of distance

Service Areas based on the distance that the population totals cover in the break distance value of 0.5km, 2km, 3.5km, 5km, and greater than 5km are analyzed based on the parcel number that in each break value it covers then each parcel contains seven population that when the projection is done for 2015 from this we can calculate the population total covered in each break value detail analyzed in table 4.6 below.

Table 4.6 Service area Served and Unserved population in terms of distance

Distance in Km	Population Parcel	Population	Percentage of Population
0-0.5	8722	61,056	19.31%
0.5-2	15,640	110,640	38.15%
2-3.5	5518	35,624	14.43%
3.5-5	5,098	35,680	11.28%
>5(Unserved)	7,608	53,250	16.84%
Total	45,181	296,246	100%

In the above result, it shows that 61,056 (19.31%) of the population total can have accessible served in 0- 0.5 km distance then 110,640 (38.15%) population can accessible served in 0.5-2km distance, 35,624 (14.43%) population accessible served in 2-3.5km distance, 35,680 (11.28%) population accessible served in 3.5-5km distance and 53,250 (16.84%) population accessible unserved in >5 km distance. According to the Ministry of Health's recommended 2km distance, the total accessible population in this range is 170,223 population from the total population of 296,246 which is 57.46% which indicates 126,024 population which is 42.54% population is inaccessible according to the recommended distance. That much amount of the population can travel or walk greater than 2km distance to get the facilities.

4.6.2 Time-Based Service Area Spatial Accessibility Analysis

In this phase of generating service areas for the facilities, the cost attribute employed is the time scenario laid made on this, the analysis was performed in 5 minutes, 15 minutes, 30 minutes, and 45 minutes time intervals. Based on the results it‘s varying according to the minimum requirement seted by the Ministry of Health by World Health Organization (WHO,2017). Within the range of 15 minutes, it is the smallest area recorded in all facilities, but more than 15 minutes to 45minute the area coverage is wider. For instance, in the range of 15 minutes to 45 minutes, The results show that it is the widest of all ranges specified on the map e.g. facilities such as the Otona General Hospital is over 28.4 km sq. which was wide in the range of 30 minutes to 45 minute. Enayat primary hospital was found to be 23.8 sq. km in 30 minutes to 45minute range, Sodo Christean primary hospital was found to be 21.4 sq. km, Tsigereda Health Center is 11.4 sq. km wide, and Ofa health center 10.1 sq. km wide, Abenezer health center is 9.6 sq. km wide to the facility by using primary and secondary road network through the speed of 60 and 40m/s respectively Within the specific healthcare facilities and their surrounding localities, the violet, and red colors and the area outside the red color are indicates low accessibility as the results displayed on the map (See Figur 4.12) below.

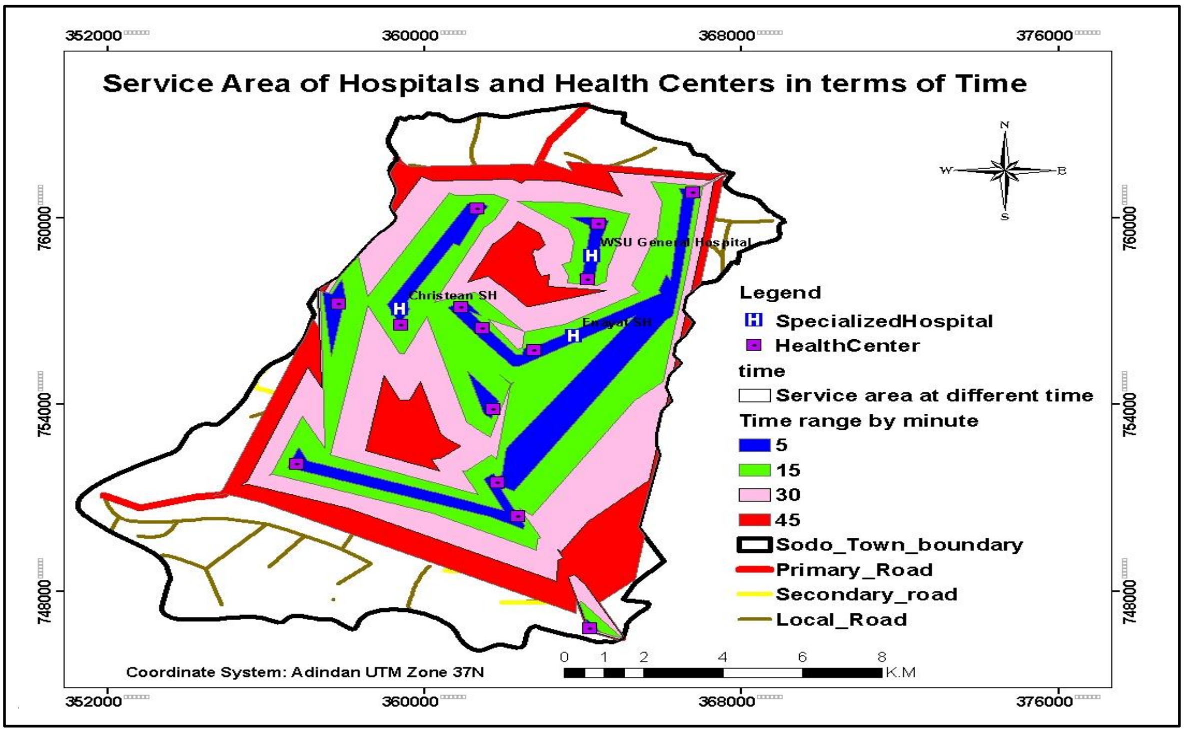


Figure 4.12 Time-Based Service Area of Hospitals and Health Center Map

Table 4.7 Health facilities and their service area coverage in time

No	Health Center	Type	Service Time Range			
			From 30-45 Minute	From 15-30 Minute	From 5-15 Minute	From 0-5 Minute
1	Yosef	Health Center	7.4Sq.km	8.8 Sq.km	5.6Sq.km	1.7Sq.km
2	Yabsira	Health Center	8.5Sq.km	10.4Sq.km	6.2 Sq.km	2.8 Sq.km
3	Tsigereda	Health Center	11.4Sq.km	9.6Sq.km	7.5 Sq.km	1.6 Sq.km
4	Enayat	PrimaryHospital	23.8Sq.km	13.8Sq.km	4.8 Sq.km	3.4 Sq.km
5	Bereket	Health Center	7.6Sq.km	5.8Sq.km	5.2 Sq.km	0.4 Sq.km
6	Sodo	Health Center	9.4Sq.km	6.9Sq.km	3.9 Sq.km	2.4 Sq.km
7	Ofa	Health Center	10.1Sq.km	5.8Sq.km	1.6Sq.km	1.9Sq.km
8	Wadu	Health Center	8.5Sq.km	8.9Sq.km	0.7Sq.km	0.9Sq.km
9	OtonaUniversty	GeneralHospital	28.4Sq.km	15.4Sq.km	10.1Sq.Km	4.8Sq.km
10	Adane	Health Center	6.2Sq.km	6.8Sq.km	0.6q.km	1.9Sq.km
11	Muluken	Health Center	8.6Sq.km	4.2Sq.km	1.2Sq.km	2.2Sq.km
12	Eskindr	Health Center	7.4Sq.km	3.6Sq.km	2.4Sq.km	1.4Sq.km
13	Abenezer	Health Center	9.6Sq.km	3.4Sq.km	0.3Sq.km	0.6Sq.km
14	Larena	Health Center	10.8Sq.km	2.2Sq.km	0.7Sq.km	2.8Sq.km
15	Sodo Chirstean	Primary Hospital	21.4Sq.km	11.4Sq.km	8.2Sq.km	4.6Sq.km
16	Lealem	Health Center	6.1Sq.km	3.3Sq.km	1.3Sq.km	2.2Sq.km
17	Bethel	Health Center	7.8Sq.km	2.1Sq.km	0.8Sq.km	0.6Sq.km
Total			193Sq.km	122.4Sq.km	61.1Sq.km	36.2Sq.km

From Table 4.7 the results show that the total area served by the public health facilities within 0-15 minutes is 97.3 km² (23.8 %), from 15 minutes to 30 minutes is 122.4 km² (29.5%), and from 30 minutes to 45 minutes is 193 sqkm (46.7%). In this result, the accessibility in the time covers much highest area coverage in greater than 30 minutes of travel time which covers 193 sq. km.

The charts in Figure 4.13 below show the service accessibility in the time interval range by graphically detailed observation.

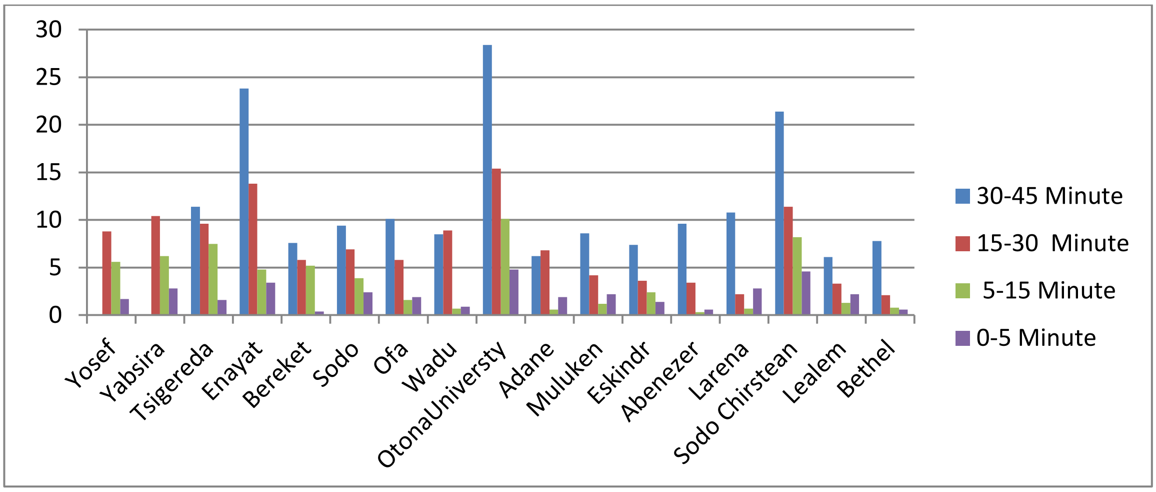


Figure 4.13 Health Facilities and Service area Coverage graphically in terms of time

Service areas based on the time that the population total covers in the break time value of 5 minutes, 15 minutes, 30 minutes,45minute, and greater than 45minute are analyzed based on parcel number that in each break value it covers then each parcel contains seven population that when the projection is done for 2015 from this we can calculate the population total covered in each break value detail analysis shown in the table 4.8 below.

Table 4.8 Service area Served and Unserved population in the Parcel in terms of time

Time (minute)	**Population parcels**	**Population**	**Percentage of Population**
0-5	7,167	50,166	15.86%
5-15	8,956	62,610	22.99%
15-30	8,635	60,450	20.65%
30-45	9,514	66,600	19.12%
>45(Unserved)	8,050	56,346	20.98%
Total	42,322	296,246	100

In the above result, it shows that 50,166 (15.86%) of the population total can have accessibly served in 0-5 minutes then 62,610 (22.99%) population can access served in 5-15minute, 60,450 (20.65%) population accessible served in 15-30minute, 66,600 (19.12%) population accessible served in 30-45minute and 56,346 (20.9%) populations unserved in >45minute. According to the Ministry of Health's recommended minimum of 30 minutes, the total accessible population in this range is 176,267 populations from the total population is 59.5% which indicates 119,980 population that is 40.5% population is inaccessible according to recommended 30-minute time. These results indicate that much amount of the population can travel or walk greater than 30 minutes to get the facility. Therefore it needs additional healthcare facilities to make it equally accessible.

4.6.3 Closest Facility Analysis

There is one government general hospital, two private specialized hospitals, and 14 health centers total of 17 healthcare facilities in the study area. The general hospital is found in the study area to provide high-level health care services especially to monitor and support closely private specialized hospitals and health centers in the study area. In this regard, it is clear that patients in the study area will find difficulties to refer for additional support or referral treatments. According to the Ministry of Health standard General Hospital should serve 60,000 to 100,000 people and it is needed in terms of providing high-quality medical care as categorized under the general level hospital. This could have been closer to supporting health in terms of health materials support, knowledge transfer, and the acceptance of treatments beyond the health facilities.

To analyze the closest facility and travel time to the health facility the study made an initial point about WSU Otona General Hospital to other health centers and specialized hospitals. It was possible to take it as a starting point at a General hospital using travel times by road transport system through vehicle and walking by foot to all others health facilities.

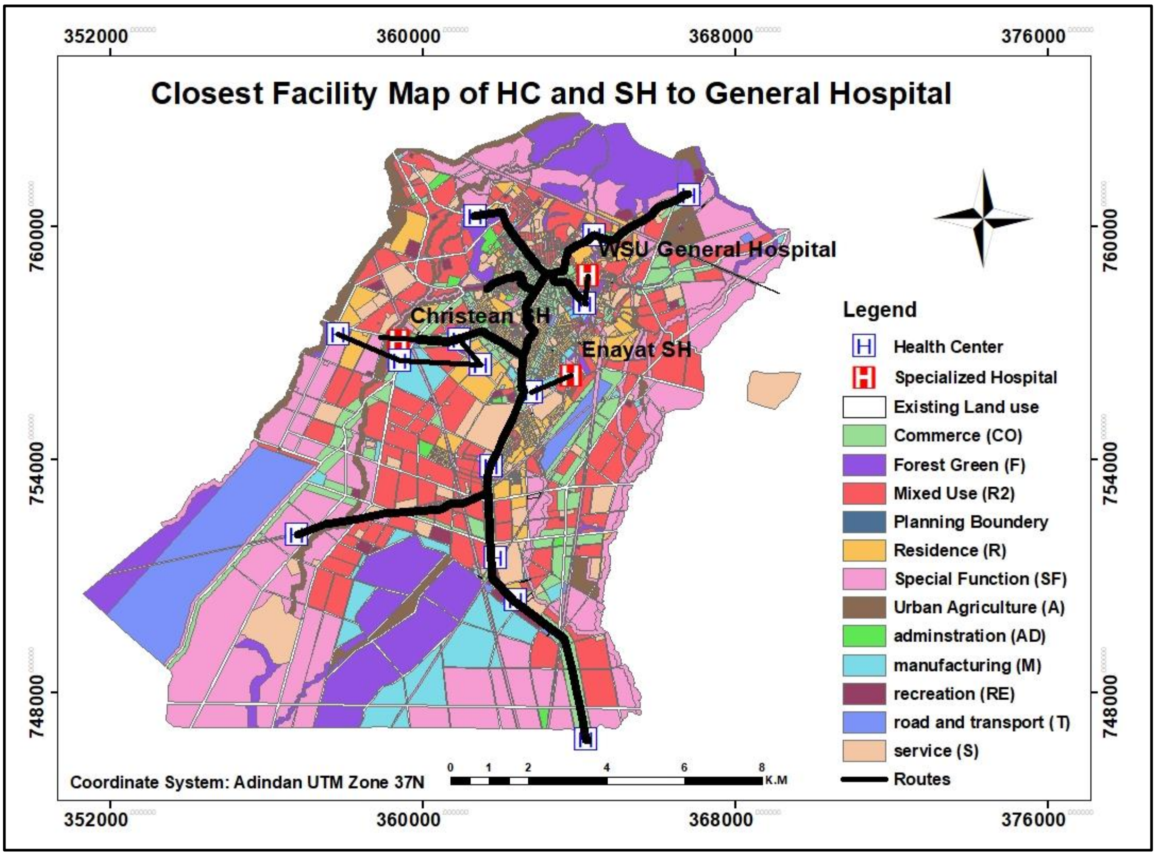


Figure 4.14 Closest Health centers to WSU Otona General Hospital

Starting routes from WSU Otona General Hospital as a benchmark to all other facilities in network analysis closest facility route generated by using the road network that produced. The result chooses the closest distance through different speeds according to the used road network in each respective healthcare facilities through vehicle transport with speed of 60m/s and 40m/s for primary and secondary road respectively used and for walking by foot 5m/s average speed used. From the result, Larena Healthcare Center is the longest distance from WSU Otona General Hospital which takes 23.4 minutes by vehicle transport and 1.2 hours by walking. Next, from WSU Otona General Hospital to Enayat Specialized Hospital takes 18.8 minutes by vehicle transport and by walking, it tooks 1.84 hours. The study reveals that travel distance via a road network to the nearest health care facilities from the General hospital to the healthcare centers and Specialized Hospitals the healthcare facilities which are Muluken HC,Adane HC and Abenezer Health center are the three nearest health centers while Larena HC,Enayat SH and Ofa Health centers are the longest distances from WSU Otona General Hospital. In addition to this the deatail analysis shown in the (Table 4.9) below and the average distance was 6.30 km and the average travel time is 14.8 minutes by vehicle and 1.40 hour by walking.

Table 4.9 Health Centers and Hospitals Closest facility result analysis

No	From	To	Driving time in (Min)	Walking time in (Hr)	Distance in (Km)
1	WSU Otona GH	Larena HC	23.4	1.92	8.45
2	WSU Otona GH	Enayat SH	18.8	1.84	7.91
3	WSU Otona GH	Ofa HC	18.6	1.77	7.83
4	WSU Otona GH	Wadu HC	17.6	1.77	7.71
5	WSU Otona GH	Bereket HC	17.3	1.71	6.92
6	WSU Otona GH	Yabsira HC	17.2	1.68	6.61
7	WSU Otona GH	Yosef HC	16.4	1.65	6.55
8	WSU Otona GH	Christean SH	15.6	1.48	6.44
9	WSU Otona GH	Tsigereda HC	14.3	1.32	6.35
10	WSU Otona GH	Bethel HC	13.7	1.30	6.31
11	WSU Otona GH	Eskndr HC	13.5	1.28	6.24
12	WSU Otona GH	Sodo HC	12.6	1.25	5.61
13	WSU Otona GH	Lealem Hc	11.2	1.15	5.54
14	WSU Otona GH	Muluken HC	9.2	0.84	4.23
15	WSU Otona GH	Adane HC	8.8	0.75	4.11
16	WSU Otona GH	Abenezer HC	8.6	0.72	3.88

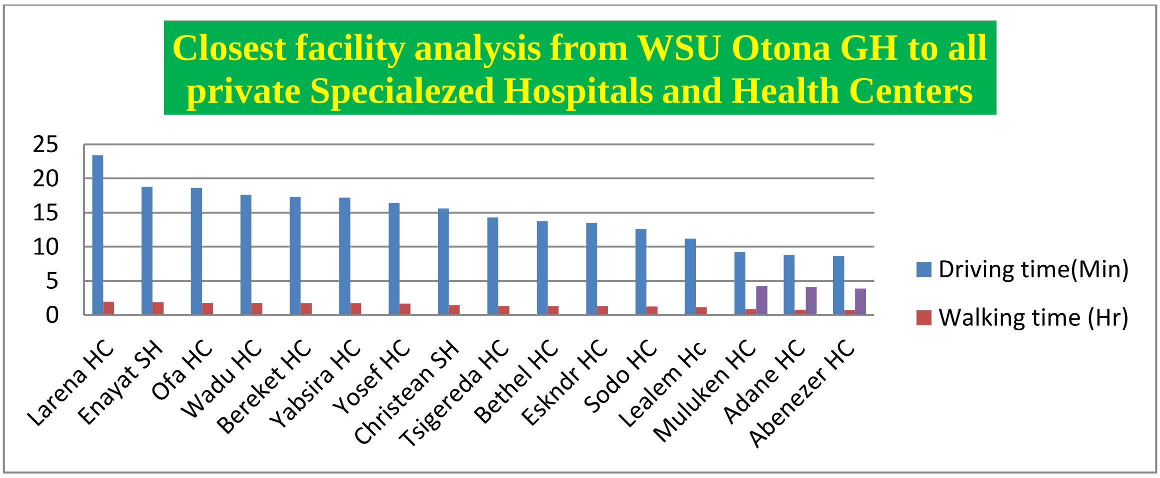


Figure 4.15 Closest facility results in analysis chart

4.6.4 OD-Cost Matrix Analysis

The OD-Cost Matrix Analysis can take the population demand location points that can analyze the options of health centers and hospitals to the population demand point. In this study, the population demand point is at the kebele block level. The block level center point of population density value considered is feature class but converted to the raster then this centered population density at kebele block level center point is considered as a demand location point. The existing Health center and Hospitals are considered facility destinations. Each block center population demand point has the option to all other health centers and hospitals by different means of transportation through network road datasets. The OD-Cost Matrix analysis determines the least cost time facility to each demand location that is nearest health center from all different options of the facility to demand location. This helps in accessibility analysis to determine the population in the given location to know which health center is best accessible to them and in the time of they need the facility to choose the best like in the time of emergency. In addition to this determining the OD-Cost Matrix analysis can helps to determine the inaccessible demand location.

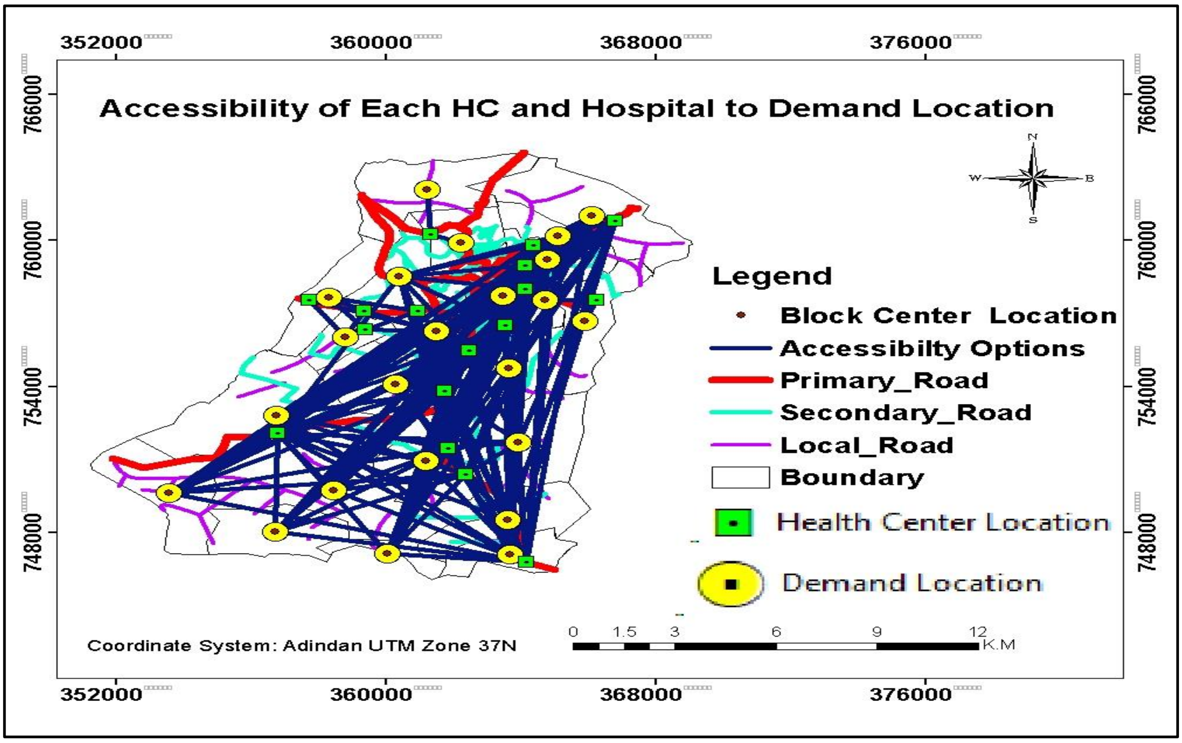


Figure 4.16 OD-Cost Matrix Analyses for Health Centers and Hospitals

From OD-Cost Matrix Analysis for each block center population center, the least cost access Health facility determined from those the least time accessibility in the (table 4.10) below from that Fana kebele to Eskindr HC least cost time distance is taken 9.44min in driving and 0.57Hr in walking, Merkato to University Otona GH 11.34 Min in driving and 0.65 Hr in Walking, Hibret kebele block center to Chirstean SH is 11.56 Min in driving and 0.67 Hr in Walking next to this Gido kebele block center to University is 13.67 Min in driving and 0.84 in walking. The largest accessibility from the least costly time accessibility is Shchora Osa to Larena HC is 56.4 Min in Driving and 2.94 Hr in Walking, Wareza Gerera to Yabisra HC is 49.34 Min in driving and 2.89 Hr in Walking, Ansombe Gembe to Yabisra HC is 46.17 Min in driving and 2.67 Hr in Walking and Bosa Kacha to

Eskindr HC is 45.76 in driving and 2.53 Hr in Walking from this least OD-Cost Matrix value the least accessibility in 30 Min driving time 13 Population block center kebele minimum distance less than 30 min driving time and 10 population block center kebele have greater than 30-minute minimum accessibility this shows there is inaccessibility of Health facility in this 10 kebele. Therefore it needs the additional health center to fulfill at least the minimum requirement of WHO standards that is a minimum 30-minute maximum distance allowed to measure the accessibility depending on this requirement the kebele Waja Kera, Wareza Shoya, Wareza Gerera, Haba Gerera, Gututo Larena, Humbo Larena, Shchora Osa, Ansome Gemba, Ofa Gandaba and Bosa Kacha are inaccessible kebele within 30 minutes driving time.

Table 4.10 The Least Cost Travel Time Path from the OD-Cost Matrix Analysis

No	From Demand location Block center Kebele	To Nearest facility	Driving time in(Min)	Walking time(Hr)	Distance(Km)
1	Waja Kero	Bethel HC	33.52	2.13	13.21
2	Dalibo Wogane	Abenezer HC	28.46	1.89	11.4
3	Kidane Mihret	Bereket HC	23.32	1.21	9.45
4	Gido	University GH	13.67	0.84	6.41
5	Wareza Shoya	Christean SH	41.57	2.67	18.89
6	Hibret	Christean SH	11.56	0.67	6.32
7	Selam	Wadu HC	15.98	1.34	7.23
8	Wadu	Wadu HC	26.32	1.79	10.46
9	Dil Betgil	Tsigereda HC	16.56	1.12	7.94
10	Fana	Eskindr HC	9.44	0.57	5.67
11	Ofa Sere	Ofa HC	19.70	1.67	8.31
12	Kera	Enayat SH	20.75	1.35	9.42
13	Wareza Gerera	Yabisra HC	49.34	2.89	21.23
14	Haba Gerera	Yabisra HC	44.53	2.56	19.23
15	Gututo Larena	Larena HC	35.78	2.23	16.78
16	Humbo Larena	Larena HC	32.23	2.14	15.31
17	Shchora Osa	Larena HC	56.41	2.96	24.45
18	Ansome Gemba	Yabisra HC	46.17	2.67	21.34
19	Ofa Gandaba	Yosef HC	32.53	2.05	15.31
20	Damota	Lealem HC	14.91	0.97	6.51
21	Merkato	University GH	11.34	0.65	5.67
22	Gola	Lealem HC	13.93	1.24	7.13
23	Bosa Kacha	Eskindr HC	45.76	2.73	20.32

4.7 Main determinant parameters used for suitability site selection in this study

In Ethiopia, as mentioned above developed standards and used for public healthcare site selection have weaknesses which mean not deliver enough and detailed information for each parameter standard. Because one parameters such as road are defined in detail. For example, their standards were developed and used by the Wolaiyta Sodo Town in the year of 2014 G.C stated that healthcare facilities must be away from factories but no detailed information about how long healthcare facilities sites should be away from it. This is why researcher the national current standards implemented across the country is not enough. So that, for this thesis the standards used by a researcher for each parameter are taken from various previously conducted researches by different scholars for suitable site selection for healthcare facilities.

Now a day different developed country had own well-developed healthcare site selection guideline and parameters to select a suitable site for healthcare facilities. For example, the healthcare site guideline of the United State of America (Healthcare Siting Guidelines , 2007) and New Health Site Selection, Processes and Criteria (Albuquerque Public Schools, 2014), and Healthcare Sites Selection and Development 44 (Kansa State Department of Public Instruction, 1976). Healthcare facilities site standards, site selection, and site development, New York the State of the health department, 1976. For this study, six parameters were identified to map suitable sites for healthcare facilities. These criteria are proximity to existing healthcare facilities, population density, transportation rout, land use, slope and manufacturing sites. All parameters are supported by a known source. Because the selected parameters enable the researcher to develop a suitability map.

Thematic map of all parameters illustrated above each Euclidean distance calculated for Six criteria‘s dataset. Then after Euclidean distance has been done the reclassification for each parameter was computed. The result of reclassified Land use, proximity distance to Existing healthcare facilities, Roads, Slope, Population Density and Manufacturing Sites are developed in scientific method and standards. Each reclassified suitability map of parameters is ordered from the most suitable to unsuitable by depending upon criteria that have been mentioned in the methodology part of this research. In the table 4.11 their standards shown below.

Table 4.11 Suitability range factors criteria for new healthcare site suitability selection

No	Percent from slope	Suitability	Score value for reclassified raster layer
1	0º -10º	S5	5
2	11º-20º	S4	4
3	21º-30º	S3	3
4	31º-40º	S2	2
5	41º-64º	S1	1
No	**Distance from Existing HC and Hospitals (In Meter)**	**Suitability**	**Score value for reclassified raster layer**
1	0-500	S1	1
2	500-1500	S5	5
3	1500-2500	S4	4
4	2500-3500	S3	3
5	>3500	S2	2
No	**Classified population Density**	**Suitability**	**Score value for reclassified raster layer**
1	0-500	S1	1
2	500-1500	S2	2
3	1500-2500	S3	3
4	2500-3500	S4	4
5	>3500	S5	5
No	**Distance from manufacturing Site (In Meter)**	**Suitability**	**Score value for reclassified raster layer**
1	0-500	S1	1
2	500-1000	S5	5
3	1000-1500	S4	4
4	1500-2500	S3	3
5	>2500	S2	2
No	**Distance from Road(In Meter)**	**Suitability**	**Score value for reclassified raster layer**
1	0-500	S1	1
2	500-2000	S5	5
3	2000-2500	S4	4
4	2500-3500	S3	3
4	>3500	S2	2
No	**Land use classes (old -values)**	**Suitability**	**Score value for reclassified raster layer (new values)**
1	Built-Up	S1	1
2	Forest	S2	2
3	Bare Land	S5	5
4	Farm Land	S4	4
5	Vegetation cover	S1	3

4.8 Reclassified Standardized Map of determinants/factors

The Reclassified and Proximity distance map of the Slope, Existing Healthcare facilities, Land Use Land Cover, Population Density, Distance from the Main Road and Manufacturing Sites are shown in (Figure 4.19) below.

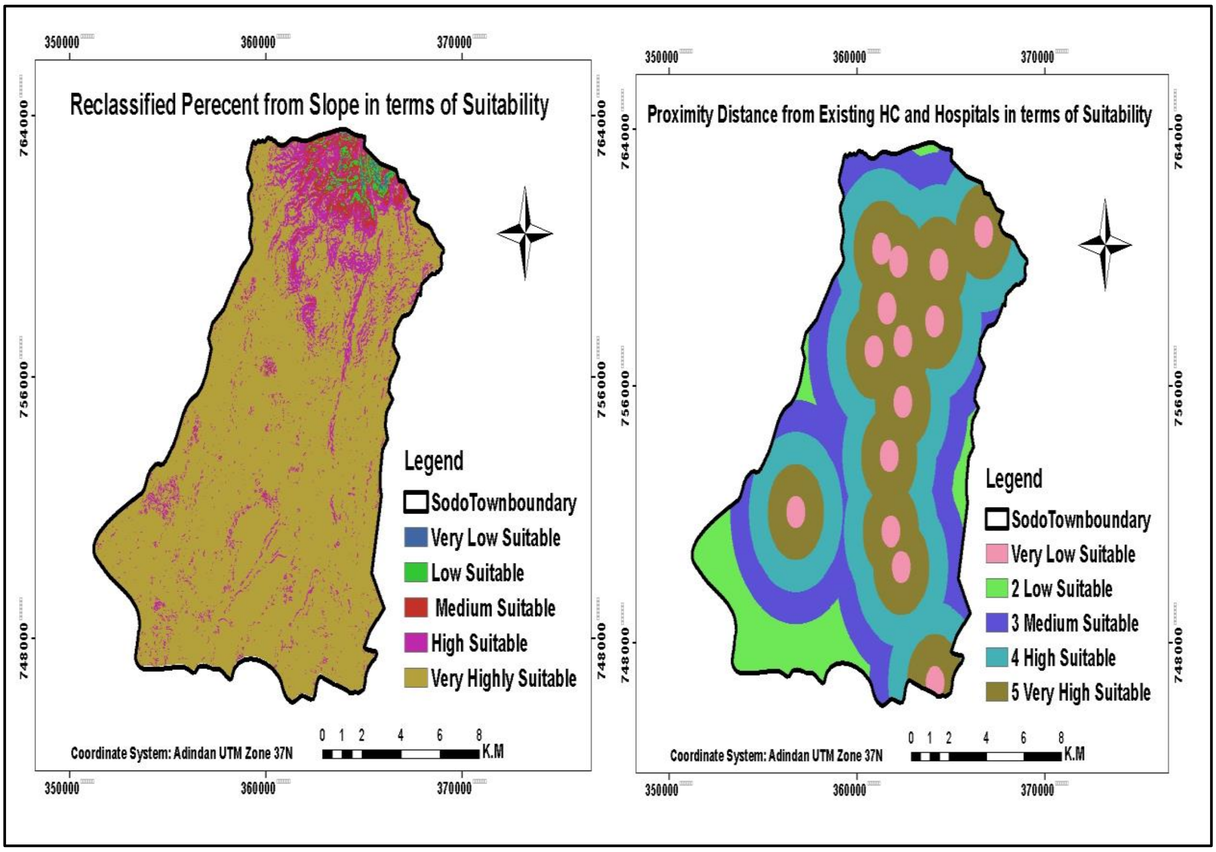


Figure 4.17 A) Map of reclassified Slope B) Map of reclassified proximity Distance from Existing Healthcare Facilities

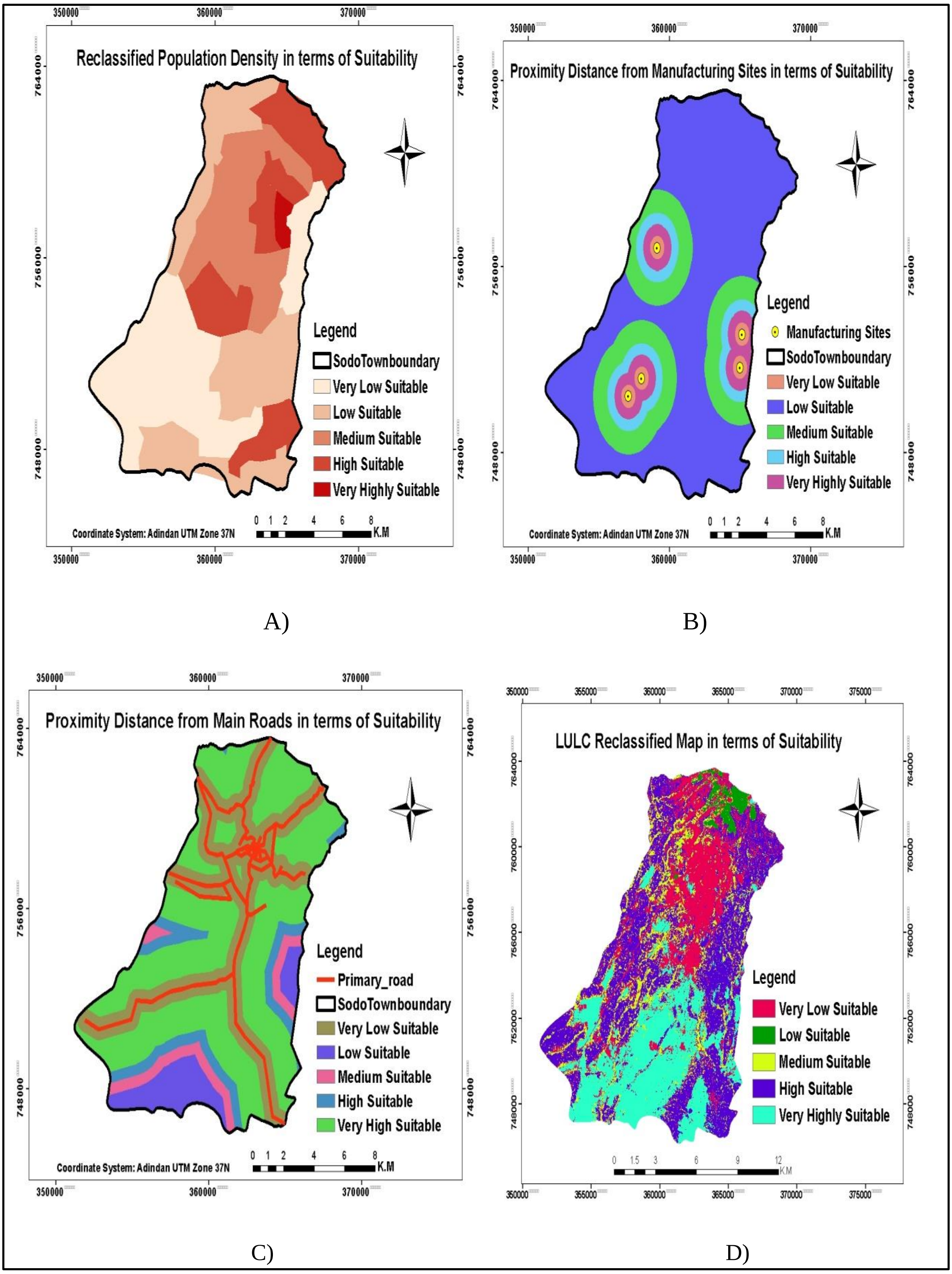


Figure: 4.18 A) Map of reclassified Population Density B) Map of reclassified Proximity Distance from Manufacturing Sites C) Map of reclassified Proximity Distance from Main Roads D) Map of Reclassified Land Use Land Cover

4.9 Ranking, Scaling, and Weighting Factor Maps

This thesis suitability model consisted of different steps: analysis of spatial distribution and accessibility, site selection constraints and suitability factors, rating and ranking the suitability factors, weighting the factors chosen, and finally performing the suitability model. The remaining procedures are described below scaling, ranking, and weighting.

4.9.1 Ranking

The raster layers were reclassified after the Euclidian distance calculation was completed. Reclassification is the process of putting relevant values (ranks) in their orderly sequence. During the reclassification procedure, this was done simultaneously. The arrangement of entities and their attributes is not arbitrarily made. During the fieldwork, document analysis, expert comments, and suggestions were used to rank and describe the suitability class values. Suitability classes are categorized into five categories: very high suitable, high suitable, medium suitable, low suitable, and very low suitable locations.

4.9.2 Scaling Value

After the suitability classes are ranked in order, the next step was to numerically value a given factor based on the extent of strength or weakness of influencing a given variable in comparison with the others. Rating refers to an evaluation, usually expressed in numerical terms, of how suitable a site is supporting a specific land use. Numeric scores to a total of five (one as least and five as most suitable) are assigned to each factor attribute class. Comparisons between classes were based on their level of suitability concerning the choice of optimal location selection for secondary school. Since environmental factors for each specific study area are different from others, there is no uniform standard for rating factors. For this thesis, however, factors are rated based on the situation of the study area, a review of literature, and suggestions from experts.

4.10 AHP Weight Derivation

An analytical hierarchy process (AHP) pairwise comparison matrix was created and criteria weights were calculated for each factor by comparing factors on a scale from 1 to 9. The reclassified input datasets were assigned a weight value to express the importance or preference of each criterion to the other criteria for suitable site selection for healthcare facilities.

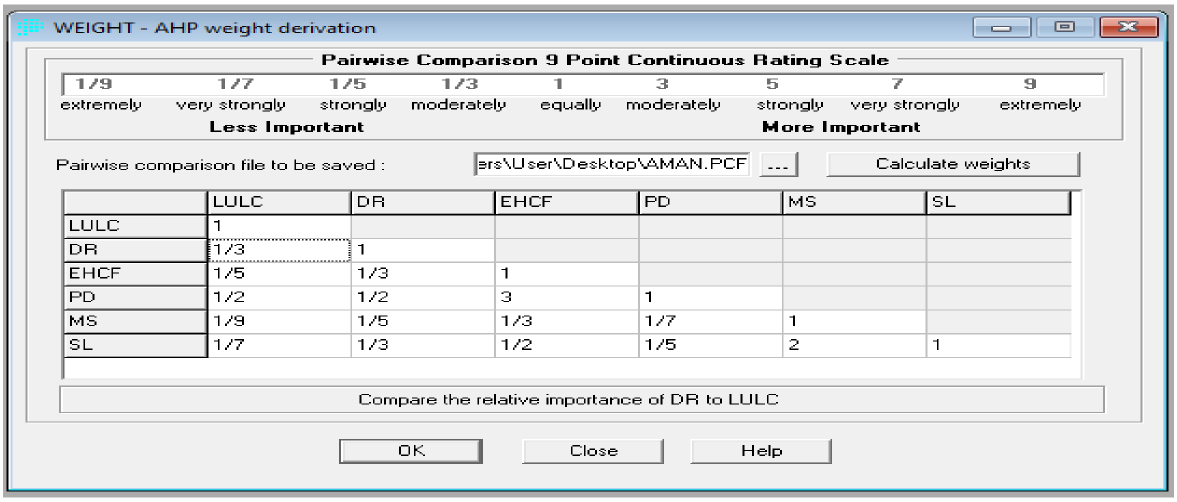


Figure 4.19 Pairwise comparison rating scale

Table 4.12 AHP Weight derivation table

	LU	DR	EHCF	PD	MS	SL
LU	1					
DR	1/3	1				
EHCF	1/5	1/3	1			
PD	1/2	1/2	3	1		
MS	1/9	1/5	1/3	1/7	1	
SL	1/7	1/3	1/2	1/5	2	1

Note: LULC_Land use Land cover, PD_Population density, MS_Manufacturing Sites, EHCF_ Existing healthcare facility, DR_Distance from the Road and SL_Slope..

Remark: In the AHP method using the data which have collected by the GPS/ interview from different organizations and Analytic Hierarchy Process (AHP) technique, a weight matrix was formed for land use Land cover, distance from the main road, population, distance from the existing healthcare facility, slope, distance from manufacturing Sites are Main criteria's. In the AHP technique, each criterion's compared with every other criterion with user define scale values. For each Main criterion's pair-wise comparison, the collected data is averaged and results are used to create a single Pair-wise Matrix by the AHP technique. (Table 4.16) is representing a Pair-wise Matrix of main criteria. Description factors to be compared for Pair-wise Matrix in Idirisi Selva software (AHP technique).

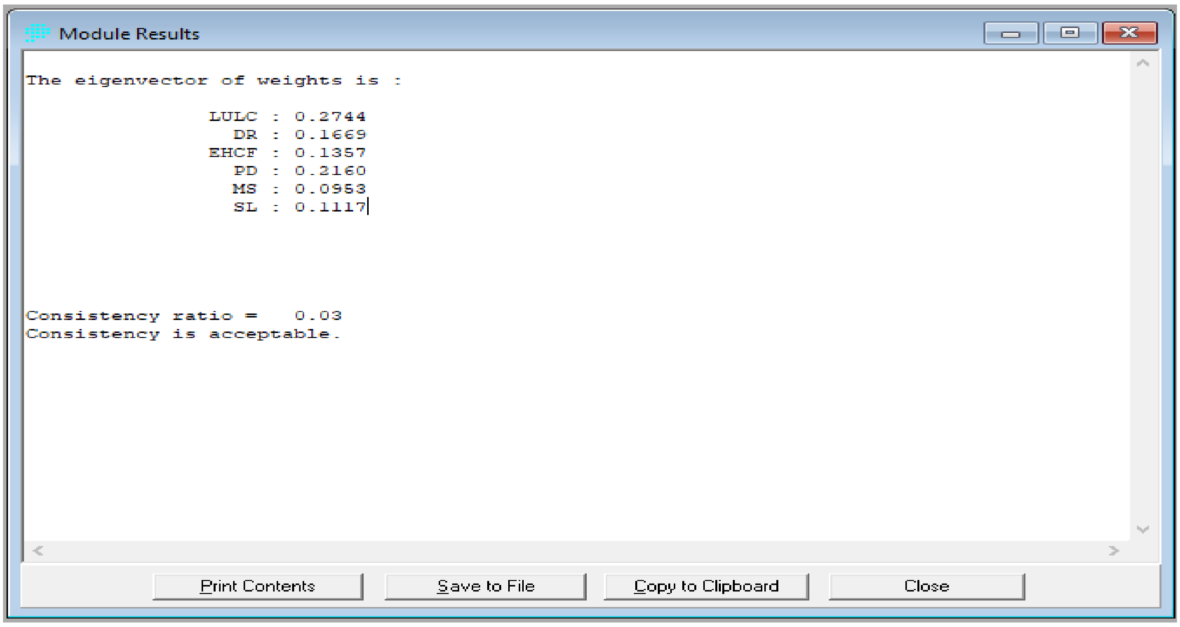


Figure 4.20 Eigenvector of the pair-wise comparison matrix

The above AHP result shows that the derived factors have a different degree of influence on healthcare facility site selection evaluation. As it is evident from (Table 4.6; Figure 4.29), the weight assigned to the factors reveals the relative importance of each parameter in exposing an area to healthcare facility location evaluation. As a result, shows Land use 27.44 % has the highest priority, Population density weight of 21.69%, Distance from the road weight of 16.69%, Slope weight of 11.17%, Existing healthcare facility weight 13.67% distance from manufacturing sites weighted 9.53% with 0.03 of consistency ratio (Figure 21). A consistency ratio of 0.1 or less is acceptable to continue the AHP analysis (Saaty, 2008).

Table 4.13 Factors Weight and their Percentages

Factors	Weighted factors	weighted percentages
LU	0.2744	27.44%
Population density	0.2169	21.69%
Slope	0.1117	11.17%
Manufacturing sites	0.0953	9.53%
Existing HCF	0.1367	13.67%
Distance from Road	0.1669	16.69%

The table above shows weighed factors calculated in Idirsi selva software based on a given data we entered in rows and column Consistency ratio = 0.03 consistency is acceptable.

4.10.1 Modeling Suitability Analysis

The 'Model Builder' in ArcGIS/Spatial Analyst was used for the healthcare facility suitability model, which is well known as the flow chart technique (Assad 2019). In the flow chart approach a healthcare suitability model was constructed from individual processes of input data, basic GIS operations, and derived data which are then linked together. The suitability model and integrated suitable site selection model are all part of the model. GIS packages and tools were used to facilitate different stages of evaluating suitable sites for healthcare facility construction in Wolaiyta Sodo town, including mapping of constraint map and factor, combining factors, identifying healthcare facility sites, and presenting GIS outputs to decision makers. The spatial analysis of the Research is shown in a Model builder workflow of all steps (figure below 4.31). The factors map is compared to each other criterion with user define scale values and weighted by AHP technique before weighted.

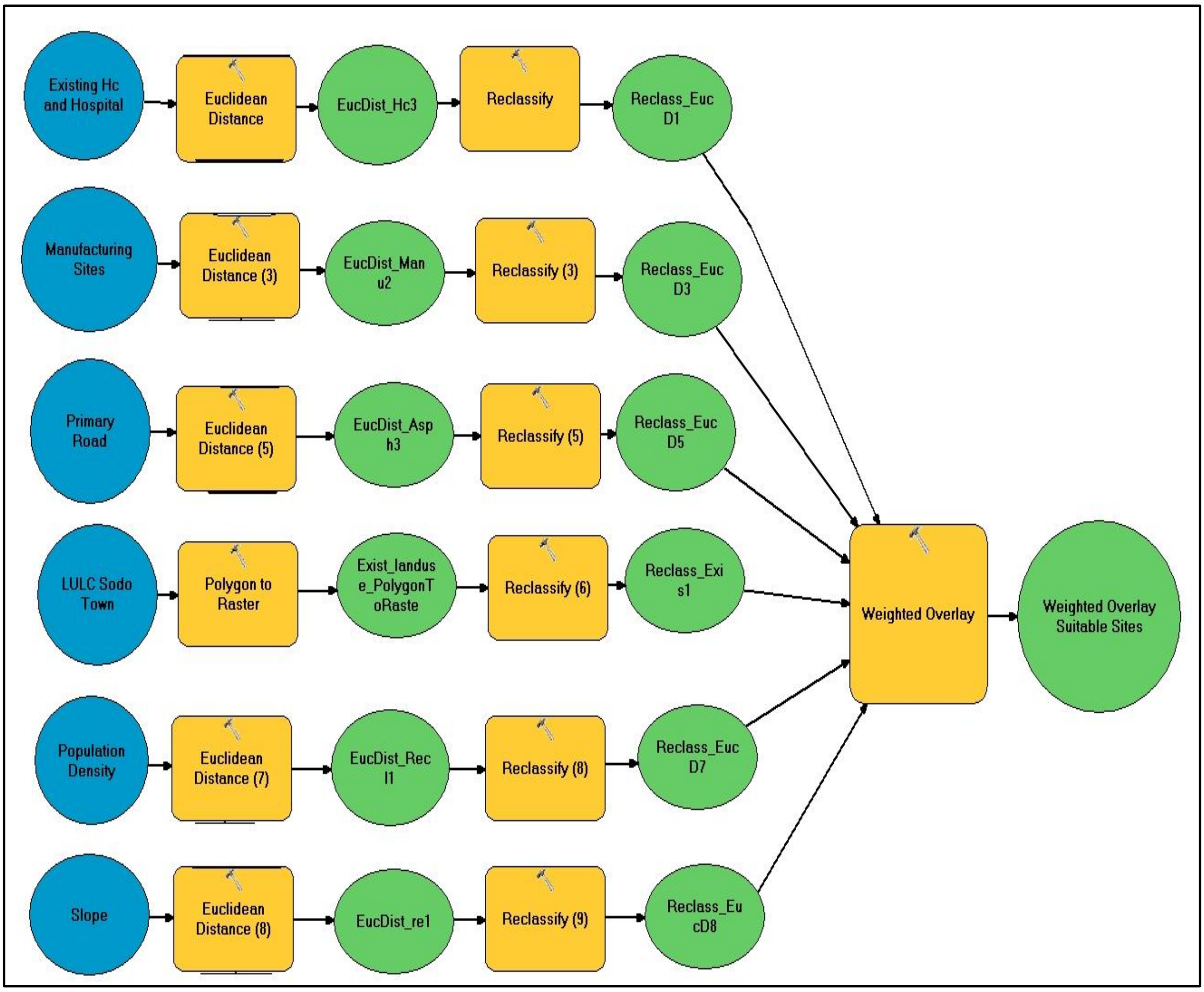


Figure 4.21 Model Builder Workflow of the Spatial Analysis

4.10.3 Weighted Overlay

An overlay of several raster inputs using a common measurement scale and weights of each according to its percentage influence is prepared (Table 4.11). The reclassed results obtained above are all combined through the weighted overlay toolset from spatial analyst tools (Fig. 4.24). The value of each overlay scale as suitability is divided into five overlay scales. Such as 1 for very low, 2 for low, 3 for medium, 4 for high, and 5 for very high suitable. In this study, the reclass scale was adjusted for the overlay scale. When the reclassified rasters are added to the weighted overlay to the value is different from the reclass scale, then it needs correctly the same as the overlay scale to reclass scale.

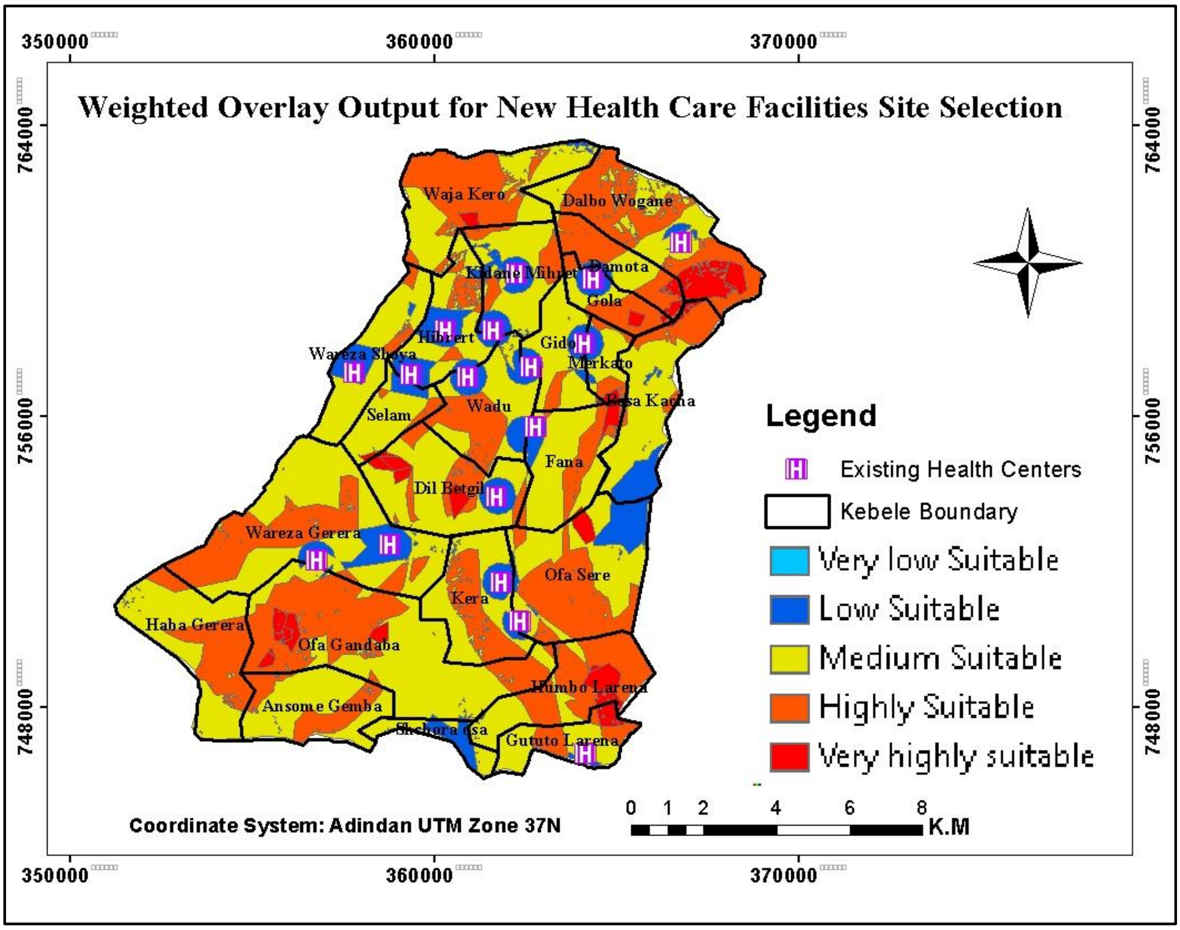


Figure 4.25 Weighted Overlay for new healthcare facilities Site Selection

According to GIS-based multi-criteria analysis, the result obtained from the overall suitability map shows 773 and 2,605 hectares are very highly suitable and highly suitable for healthcare facility development. The large area is medium suitable for healthcare facility development in the existing situation which covers 48.6% (5,568 ha) of the area. The remaining 19%(2,180ha) and 2.92%(324ha) are low suitable and very low suitable for healthcare facility development respectively (Table 14). In the land use plan, the selected areas are mostly categorized as open space/ bare land.

Table 4.14 Final suitability area and percent of total area coverage

Level of suitability	Area(Hectare)	Percentages of total area (%)
S5 (Very highly suitable)	773	6.75%
S4 (High suitable)	2,605	22.75%
S3 (Medium suitable)	5,568	48.60%
S2 (Low suitable)	2,180	19%
S1 (Very low suitable)	324	2.92%

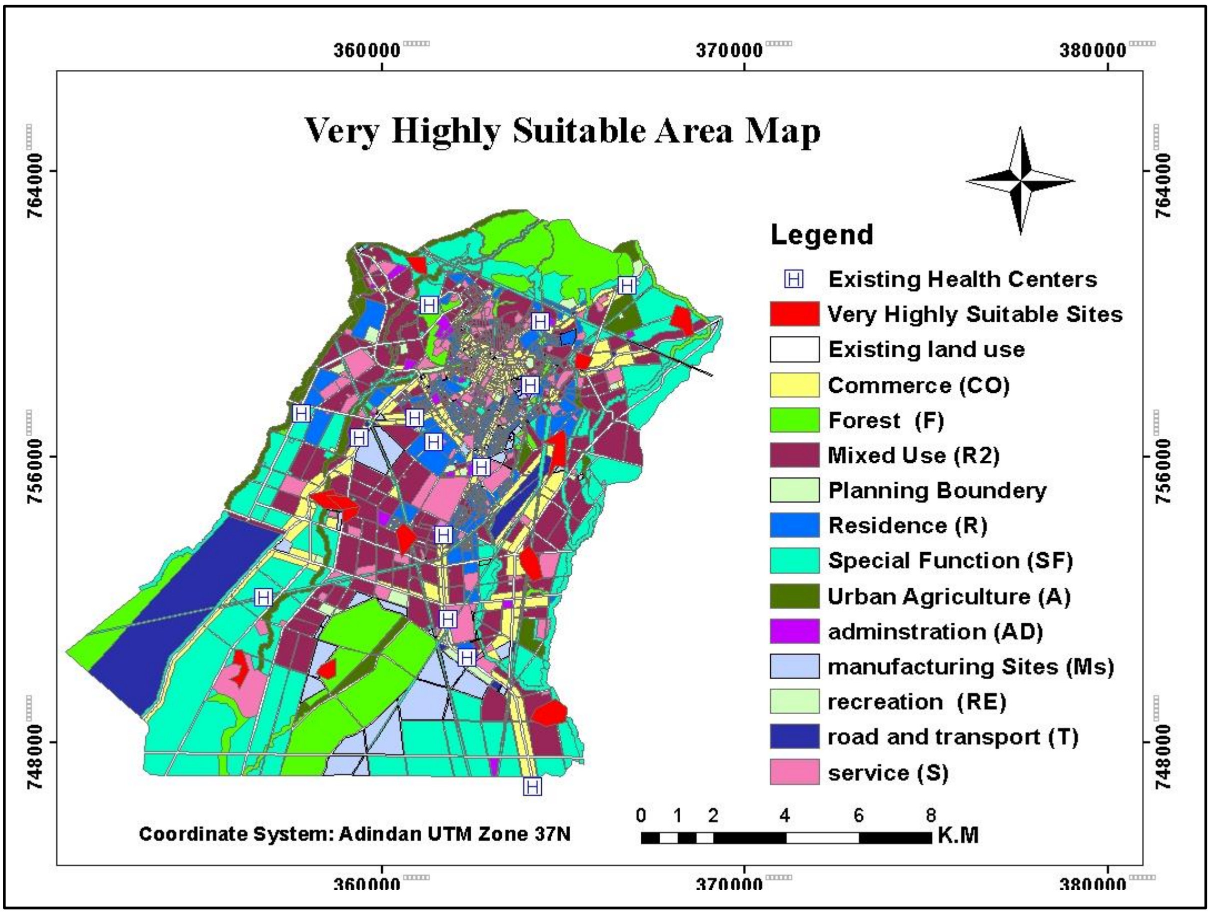


Figure 4.26 Very Highly Suitable Areas for new Healthcare facility construction

As indicated the map is the Very highly suitable sites and are the best preferable sites of public healthcare facilities construction. These sites are those which most satisfy the standards of the criteria used in the suitability model. Therefore, healthcare facilities are preferred to be constructed on these sites.

4.11 Discussion

The main objective of conducting this research is to analyze existing healthcare facilities and to find results on how to balance distribution and establish the new healthcare facility service site near the population (demand) environment. Various factors are investigated to achieve the intended goals. It is seen through Fig. 4.1 that concentration of health centers and hospitals in the study area shows inequality in the town most of their concentration in the central part of the town mostly the northwestern part and the correlation between the health facilities and the total number of the population are related by 0.005 significance value with 95% confidential level their correlation value is 0.534 that is moderately related with the coefficient of determination value 0.285 which indicates the 28.5% concentration of healthcare facilities depends upon the population this value is shown a less relationship between them.

The total population of the town projected in 2015 is 296,246 used in the distribution at each kebele level considered the allowed recommended distribution of health facilities by the Ministry of Health. The result shows that by differentiating the requirement meets and un meets the distribution of 10 kebeles have no health facility from 23 kebeles 3 kebeles has exceeds distribution and the remaining 10 kebeles meet the recommended standard.

The result of the services area analysis based on travel distance set in five distances 0- 0.5 km distance 61,056 population 19.31% of the total population can accessible in this range, 110,640 population that is 38.15%of total population in 0.5-2km distance accessible, 35,624 population that is 14.43% from total population accessible in 2-3.5km distance, 35,250 population that is 11.28% from total population that is accessible in 3.5-5km distance and 53,250 population that is 11.28% from total population is accessible in >5 km distance. According to the Ministry of Health's recommended 2km distance, the total accessible population in this range is 170,223 populations from the total population of 296,246 that are 57.46% which indicates 126,024 populations that is 42.54% population is inaccessible according to the recommended distance. The second SA analysis by using travel time impedance interval of the same basic data set in five-time scenarios 50,166 is 15.86% of the total population can have accessible in 0-5 minutes then 62,682 population is 22.99% that can accessible in 5-15minute, 60,450 population that is 20.65% accessible in 15-30minute, 66,600 population that is 19,12% from total population accessible in 30-45minute and 66,346 population that is 20.08% accessible in >45minute. According to the Ministry of Health recommended minimum of 30 minutes the total accessible population in this range is 171,705 population from the total population of 296,246 that is 57.96% which indicates 124,541 population that is 42.04% population is inaccessible according to recommended 30-minute time. These results indicate that much amount of the population can travel or walk greater than 30 minutes to get to the facility. Therefore it needs additional healthcare facilities to make it equally accessible.

Depending on those spatial distribution analyses and service area analyses the researcher selected new additional healthcare facilities suitable site by using GIS-based multi-criteria decision analysis through analytical hierarchy pairwise comparison weighted analysis. Although AHP weighted linear combination have been extensively used in developing land suitability maps in several diverse situations, there is no commonly accepted method for assigning the relative weights to the criterion maps (Malczewski 2004). As a result, different weighting schemes can produce different outcomes (Chakma 2014). For instance (Heywood, Oliver, and Tomlinson 1995) reveals different multi-criteria evaluation rules result in different suitability patterns. Therefore, this study used six site selection criteria (proximity to the main road, land use land cover, slope, population density and existing healthcare facility) used to select suitable site for healthcare facility service in Wolaiyta Sodo town. The result obtained shows 773 ha (6.73%) and 2,605ha (22.75%) are very highly suitable and highly suitable for healthcare facility development. The selected area are mostly categorized as open space/bare land and Shrub land were considered to be highly suitable and moderately suitable for constricting new healthcare facility development respectively. The final map shows that 5,568ha (48.6%), 2,180ha (19%) and 324 (2.92%) of the study area has been identified as medium suitable, low suitable, and very low suitable for healthcare facility development respectively (see figure 4.25). Accordingly, selecting and identifying suitable sites for healthcare facility development requires the accurate use of geospatial technology to assist in an effective planning process of suitable healthcare facilities sustainably.

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The present study was designed to examine spatial distribution, concentration, patterns, and accessibilities level of the existing healthcare facility to the residents and to select suitable site for new healthcare facility construction in Wolaiyta Sodo Town using GIS-based integrated MCDA.

The study revealed that the spatial distribution in the study area with reference to (FMOH,2017) standards ten kebeles have no healthcare facilities found that unmeet requirements, eighth kebele meets the requirements and remaining five kebeles are over distributed which un meets the requirements. The spatial distribution patterns in study area neighrest neighborhood analysis value results Rn = 1.355265 indicates more random distribution of existing healthcare facilities in study area. Depending up on this results in study area there is no planned mode of health center distribution in the demanding environment of the community so healthcare facilities are highly concentrated in infrastructure and utility-filled areas

The spatial accessibility of existing healthcare facilities in terms of distance and time 2km and 30 minutes recommended maximum distance and time to reach the healthcare facilities respectively by ministry of health. Residents in Wolaiyta Sodo town could get the nearest healthcare facilities within a 2km distances accessibility are 125,934(42.51%) and 170,312 (57.49%) populations are accessible in >2km distance. The time-based service area analysis result shows populations of 157,900 (53.3 %) are accessible within < 30 minutes and 138,347(46.7%) populations are accessible in > 30 minutes from the total 296,246 populations. This result indicates the most of peoples in the town gets the health facilities by traveling more than 2km distance or 30 minute which needs additional healthcare facilities construction for those inaccessible areas in the town.

Thus, proximity to (transportation) roads, existing healthcare facilities, slope, population density, manufacturing site and land use land cover sites are essential criteria for the new healthcare facilities suitable site selection by considering the existing one to ensure accessibility level as recommended Ministry of health standards. The use of MCDA, GIS and remote sensing techniques was successfully demonstrated for spatial distribution and identifying accessibility levels and to select new suitable sites shows 773 ha (6.75%), 2605 ha (22.75%) and 5568 ha (48.6%) of the study area has been identified as very highly suitable, highly suitable, and medium suitable for healthcare facilities development respectively. The remaining 2180 ha (19%) and 324ha (2.92%) of the study area have been identified as very less suitable and unsuitable sites respectively.

The proposed method in this research is economical, less time-consuming and more productive than the traditional approaches to potential site selection for locating healthcare facilities. In this case, planners and decision-makers can reduce field visits and survey by mapping new additional the spatial location of the healthcare facilities in the Sodo town in order to meets the requirement to Federal Ministry of Health (FMOH, 2017) standards.

5.2 Recommendation

The findings of this particular study have shown that Geospatial technologies and GIS-based multi-criteria analysis (MCA) are important tools for studies to analysis the spatial distribution, accessibility, and select new suitable sites for public healthcare facilities development. Having carried out this research, the following recommendations have been outlined.

- The Ethiopian Ministry of Health has a standard regarding healthcare service distribution and accessibility but is not applied practically in the study area. Therefore, this research study gives insight for the decision makers and planners to incorporate such scientific analysis of spatial accessibility and to select suitable sites to ensure sustainable land planning and management.
- The spatial data of the land use plan in the study area has no reserved places for healthcare facilities building purposes. So that Sodo Town land planners and relevant bodies shall take into consideration how to deal with such matters for the future fast-growing urban population.
- In the study, Catchment area is not available instead, administrative boundaries were used for further analysis, but it would be better to have a health service catchment area in its own right to provide medical care.so that the healthcare service providing catchment area map should be studied.
- Although this study provides important information on the spatial distribution of healthcare facilities in Sodo Town and major influencing factors. Hence, further research is needed on several fronts, and more studies are recommended in other urban centers in the country, as comparative analysis would provide an increased understanding of effective social service planning.

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APPENDICES

Appendix I: Coordinates of Existing Healthcare Facilities

No	Healthcare facility	Type	X Coordinate	Y Coordinate
1	Yosef	Health Center	363843.7632	758062.1314
2	Yabsira	Health Center	365232.6251	759434.4276
3	Tsigereda	Health Center	363362.6532	757442.9173
4	Enayat	PrimaryHospital	363223.9861	757113.9176
5	Bereket	Health Center	367643.5674	756383.7638
6	Sodo	Health Center	364338.2322	757946.8214
7	Ofa	Health Center	358194.6745	744598.9167
8	Wadu	Health Center	363682.7461	757261.1456
9	OtonaUniversty	GeneralHospital	364953.8341	758255.2136
10	Adane	Health Center	363445.1265	758312.4326
11	Muluken	Health Center	363198.6742	756545.3145
12	Eskindr	Health Center	369324.3216	759732.5632
13	Abenezer	Health Center	358643.7291	746832.1346
14	Larena	Health Center	35576.7354	74535.3246
15	Sodo Christian	Primary Hospital	363034.8223	757884.3754
16	Lealem	Health Center	362515.6534	757367.0783
17	Bethel	Health Center	365734.2413	754687.8601

Figure 1. WSU Otona General Referral Hospital

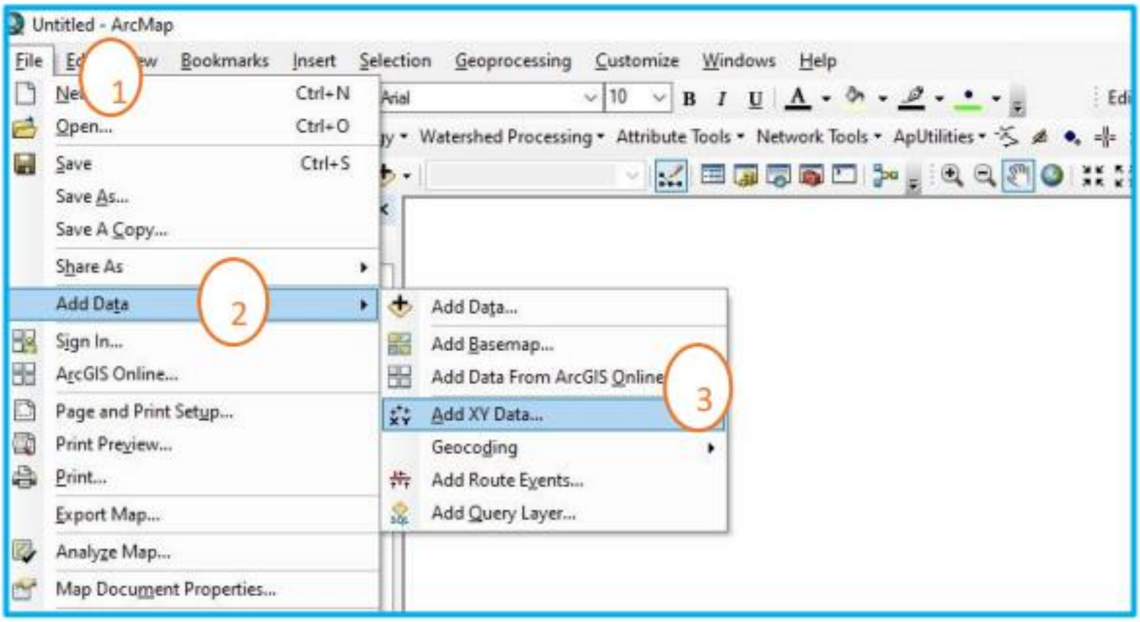
Appendix II: Location of The Main Manufacturing and storage in the Sodo Town

No	Manufacturing site	X Coordinates	Y Coordinates
1	Powder (ዱቄት) and Beaker factory	356874.2634	746243.0045
2	Food processing & Bevearage	369613.8912	758637.4836

Appendix II: LULC error matric table which used for service area analysis.

	REFERENCE DATA (2023)									
CLASSIFIED DATA (2023)	LULC	Built up	Bare land	Dense forest	Sparse forest	Permanent crop	Wood land	Annual crop	Total points	U.A (100%)
	Built up	41	1	1	0	2	2	1	48	84.35
	Bare land	0	43	0	1	0	5	2	51	91.32
	Dense forest	0	0	44	3	0	0	2	49	87.76
	Sparse forest	3	0	0	40	3	0	3	49	92.65
	Permanent crop	2	5	0	0	45	1	1	54	88.41
	Wood Land	1	2	0	2	2	42	0	49	93.24
	Annual crop	2	1	2	1	0	1	43	50	86.75
	Total Points	49	52	47	47	52	51	52	350	
	P.A(100%)	86.74	81.52	94.21	89.34	91.51	89.67	79.90		
	Overall Accuracy =87%									
	Kappa Coefficient (K) =0.83									

Appendix III: Adding and Displaying Downloaded Data in ArcMap



Appendix IV: Table. Data collection format

Manual Data Collection Gps Field Book						
Point No	Name Of Site	Site No	Northing	Easting	Elevation	Remark