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FACULTY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF SURVEYING AND GEOMATICS

TOPIC

OPTMISATION OF PRIMARY HEATH CARE FACILITY LOCATION, CASE OF GWERU DISTRICT.

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DEDICATION

I would like to dedicate this dissertation to my late mother Sithembile Marashanye who taught me to preserve and prepared me to face the challenges with faith and humility. She was constant source of inspiration to my life. Though she is not here to give me strength and support I always feel her presence that urge me to strive to achieve my goals in life. Rest in Peace.

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All praise, honour and glory be to my Lord Jesus Christ for His grace and mercy for the accomplishment of this dissertation. Without His blessing this achievement would not have been possible.

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Finally my deepest gratitude to my family for their prayers and support which raised me to this level.

Once again I thank you all

ABSTRACT

As access to health care is a human right in Zimbabwe it is expected that primary health facilities should be optimally located to serve demand. It is therefore a challenge for the government and policy makers to provide primary health facilities which are optimally located to serve demand conveniently. This paper highlights a GIS method for optimising location of primary health care facilities. The study area is Gweru district in Zimbabwe. Using location allocation models in ArcGIS optimal location of primary health facilities in Gweru district were selected and also the existing locations were assed to see if they are well located to serve the population as well. The important factor of locating primary health care facilities is the location of demand that require health services from a Primary health facility, here the population dataset downloaded from World pop website was used to estimate the distribution demand. Spatial accessibility is the essential principle of primary health care hence it is important to consider the relations between the location of demand, location of PHCs and the method of transport linking people with the services .in this study road network downloaded from open street was used to link facility and the demand. Also candidate facilities were obtained from the fishnet grid and the existing facilities were downloaded from the humanitarian data exchange. Maximize capacitated model was utilised to obtain the theoretical optimal location of primary health facilities in Gweru district and it was found that 68% of the population is served by the locations. Then the current distribution PHCs and their catchment area were evaluated, only 37% of the demand have good access to health care. Finally the results from the theoretical locations were compared with the existing locations. Results indicated that most of the people residing in rural areas were outside the service area as defined by the standard travel distance of 5km.The comparison results indicate that the existing facilities are not optimally located and the have low accessibility than the intended locations.

TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF ACRYNOMS

ESRI- Environmental Systems Research Institute

GIS - Geographic information system

PHC-Primary health care

WHO-World Health Organisation

1. CHAPTER ONE

1.1 Introduction

Health centres directly add to the health of the individuals and communities. Primary health care facilities are responsible for the public health and they usually belong to state authorities. They provide quality health services, primary care as well as health education. (TARSC and CWGH, 2009) illustrated that primary health care aims to respond impartially, suitably, and viably to fundamental heath needs and to address the essential social, financial, and political effects of poor health, to enhance availability to basic health services and to include the participation of communities. Primary health care facilities are required to be optimally distributed in order to archive their goals and serve the population.

Poor location of primary health care facilities results in a number of problems which include adverse pregnancy outcomes, decreased vaccination coverage, increased infant mortality and decreased contraceptive use (Tanser, 2006).To solve these problems proper location of primary health facilities is required. Geographic information system (GIS) has a number of analysis tools that are used to determine optimal site (Witlox, 2005). Thus this research is aimed to determine the optimal location of primary health care facilities in Gweru district through the use of geographic information system.

1.2 Background

In Zimbabwe health service is delivered through are primary, secondary, tertiary and quaternary health care. In the country health services are mainly executed through PHCs and fundamental components of primary health care incorporates maternal and child health services; health education; nutrition education and food production; expanded programme on immunization; communicable diseases control; water and sanitation; essential drugs programme; and the provision of basic and vital preventive and curative services.(Madzorera and Gwinji, 2009)

Through the National health strategy, the government of Zimbabwe recognises equity in health care, universality and quality as the essential principles in the delivery of health care services(AIDS & TB Unit, Ministry of Health & Child Welfare, 2013). The principle of universality calls for measures that confirm that all people have access to primary health care facilities. In order to achieve this, efficient methods should be applied in locating health care facilities so as to ensure accessibility. Primary health care prevent the spread of diseases if they are optimally located. According to (Starfield and Shi, 2007), primary health care is viewed as the best way of reducing imbalances in health care services.

Geographic information system methods efficiently focus on relevant population needing health care services and accomplishing universal health coverage (Roth et al). Geographical information systems are often used in site selection problems to efficiently determine the optimal location of finite resources. (Tanser ,2006) took into account travel time, the distribution of the health services, distribution of the population they serve and applied GIS technology to efficiently site new facilities in order to achieve the maximum population level increase in accessibility to primary health care. In 2012 Zhou and Wu adopted GIS-based multicriteria analysis to select a site for building a new hospital in Haidian District. Ahmed *et al* (2016) integrated Geographical Information System (GIS) with Analytical Hierarchy Process (AHP) to develop a Multi-Criteria Decision Support System (MCDSS) to determine the optimum site for a new hospital in the Aswan urban area.(Thosso ,2007) used GIS to develop a landfill site selection model in Bloemfontein, Lesotho. The application of GIS in site selection is also functional in Zimbabwe. In 2017 Zulu and Jerie conducted a study in which they used GIS to map the optimal sites for locating a dumpsite in Bunkent.

According to Thomas and Penchalsky 1981 as sited by (Alfaqeeh, Ghadah, 2015) Access to health care is defined in terms of availability and physical accessibility. Availability is the number of people per facility and physical accessibility is the location of facility in relation to that of demand. Primary health facilities reduce inequalities in health service delivery if they are well located. The current method used in establishing these facilities does not consider the spatial distribution of the population .In Zimbabwe there is no documentation on how the location of primary health care facilities was determined. Information obtained through communication with the Gweru city council urban planner portrayed that primary health care facilities are located based on population density .With the guidelines of the Regional town and country planning act(RCTP) of Zimbabwe and master plan planners considered different factors for establishing primary health facilities such population, topography and required space. However the number of people require health service (population) is the key factor.

Currently Planners utilize stands or housing units and house density population to locate at least one facility per neighbourhood each neighbourhood having a population of about 10 000 people. With this concept only the availability component of access to health is considered. The current methods determine the demand using stands and housing density. The assumption is that each housing unit has a population of 6 people which might not be true. Also the facility is located and the central point of the demand and travel distance from demand to facility is measured in straight line, they make use of buffer zones which is not appropriate since people travel through a road network.

In order to improve access effective methods should be applied in locating primary health facilities and evaluate if the existing facilities are well located to serve the population.

However this study is aimed to utilize geographic information system method to optimally locate the primary health facilities in Gweru district with population per facility and travel distance through the road network from demand to facility as the key factors of measuring accessibility.

1.3 Problem statement

Spatial accessibility is the interaction of health facility location, demand location and mode of transport used to link demand with the facility. To ensure sustainable health service delivery in Zimbabwe primary health facilities should be optimally located. The service provider ratios are utilised but they are failing to meet the expectations of sustainable health delivery system. Current methods utilised in establishing location of primary health care facilities does not consider the spatial spread of the population. This is shown by long queues, waiting times as well as travelling long distances to health care facilities which indicate poor accessibility and proclaim decline of sustainable service delivery. Also travel distance from demand to facility is measured in a straight line which is not appropriate since people travel through the road network and this impede accessibility since people will be forced to travel distance which is more than the recommended ,therefore enhanced methods and tools should be used for determining the optimal location of primary health care facilities and also for evaluating the accessibility of existing facilities so as to identify areas with shortages and allocate resources in order to improve accessibility.

However this study is aimed to utilize geographic information system method to optimally locate the primary health facilities in Gweru district with population per facility and travel distance through the road network from demand to facility as the key factors of measuring accessibility.

1.4 Objectives

- To determine the theoretical optimal location for primary health care facilities in Gweru district.
- To evaluate if primary health care facilities in Gweru district are optimally located to serve the population.

1.5 Research Questions

1. On theoretical basis, what are the optimal location for primary health care facilities in Gweru District?
2. How do the intended optimal location compare with the existing locations?

1.6 Justification

There are other methods currently being used for locating the new sites for primary healthcare facilities, but in this study there is intended to be made use of GIS technology as it has proved to be more efficient in other studies of similar problem. With GIS access to health care facilities can be improved by locating primary health facilities on optimal sites (Wit lox, 2005). s(Mclafferty, 2013) illustrated that geographic information system technology provides a number of tools that help health planners to understand the geographic variation in population and population need for health care services. In 2000, Dikshit *et al* elaborated that GIS technology is capable of handling large amounts of complex geographic data and significantly aiding the facility siting process .In that way the research is going to bring a solution to problems that were being encountered by the citizens of Gweru in as much as the site locations of primary healthcare facilities is concerned.

1.7 Methods

The first objective was solved by using population dataset and road network dataset for Gweru District. Population dataset was downloaded from world pop website .the dataset was obtained in raster format and was converted to points so as to get the population distribution. The road network datasets was downloaded from openstreet.Road network dataset has missing roads on the rural side of the district, manual digitizing was conducted to fill the missing data. Candidate facilities for were established by creating a fishnet grid of points, then a network dataset was developed. A location allocation analysis was performed between the candidate facilities, road network and population using location allocation tool in ArcGIS to determine the optimal locations for primary health facilities, the intended locations were compared with the existing location to see how well the current facilities are located to serve the population in Gweru district.

1.8 Research Structure

The research is organized into five charpters.The first chapter is consisted with the introduction and background of the study .It also presented the research problem, research objectives and the main research questions.Chapter2 is literature review which highlights the relevant literature relating to finding optimal site location for primary health facilities. It also provides an overview of geographic information system, its applications in facility location and the methods used to determine optimal locations for health facilities.Charpter3 is the methodology on which the methods used to answer the research questions and address the research objectives are highlighted. It provides the data sources, the procedures used to collect, process and analyse the data.Chapter4 is about the presentation of results. It provides the discussion and analysis of results obtained from the procedures carried out from the methodolody.it present how the locations determined from the steps in chapter3 compare with the existing locations .Chapter 5 is the final chapter of the research which provides the recommendations and conclussions.It summarises the key findings of the research and provides recommendations to the decision makers

2 CHAPTER TWO

2.1 Literature review

This chapter is aimed to review the critical points of current knowledge including key findings related to the application of geographic information system technology in determining the optimal site location for primary health facilities. In this chapter the researcher will review articles published on the concept of primary health care, an overview of GIS, access to health care, application of GIS in site selection and the methods used in determining optimal sites for health care facilities.

2.2 Concept of primary health care

Primary health care is viewed as health care accessible to every individual in the community at affordable cost and with their full participation(Starfield and Shi, 2007). Primary health care has played a pivotal role in promoting human well- being, improving people's health and building a harmonious nation. It is the basis of care and more often the first point of contact that individuals have within the health care frame work(Medicine and Review, 2015).Primary health care contributes to the economic development of a nation and it also frames the vital part of the nation 's health system. According to(Guagliardo, 2004) if PHC facilities are optimally located the effectively reduce imbalance in health care delivery and prevent the spread of disease.

Primary health care focus on providing the following components

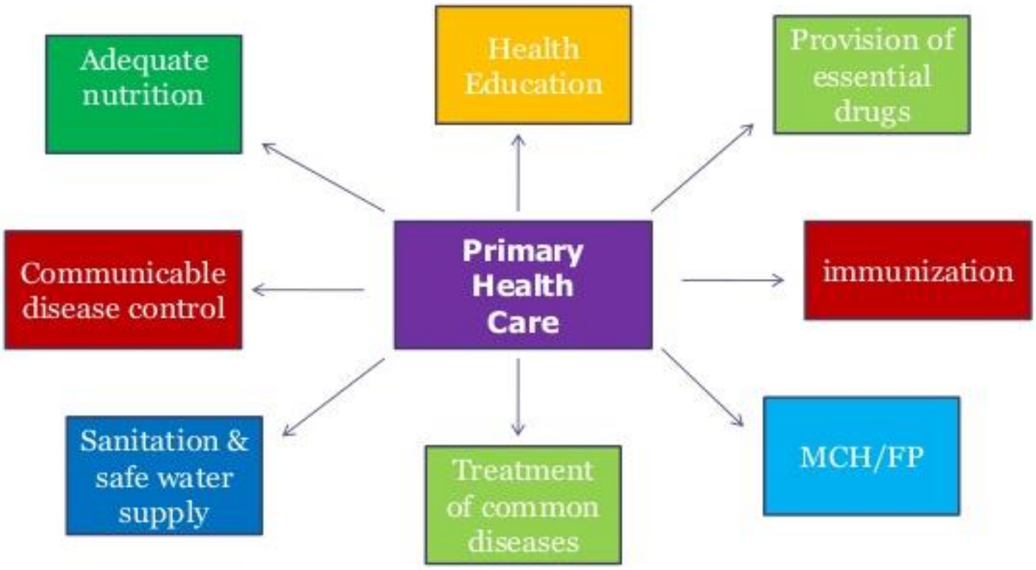


Figure 1 Components of primary health care

2.3 Factors used to determine best sites for primary health care facilities

In order to identify optimal site location for primary health care facilities, there are certain factors that must be considered. According to Kao and Lin (1996) as sited by (Thosso,2007) , It is vital to include criteria from the social, spatial, economic, political and ecological dominions of the problem. Youzi *etal* (2017) illustrated that in order determine the best suitable sites for primary healthcare facilities, there are principles and indicators that should be considered and these are access principle, distance principle, neighbourhood principle, radius of service area and population criterion.

2.4 Geographic information system (GIS)

According to Environmental Systems Research Institute (Esri, 2012) Geographic information system (GIS) is a collection of hardware, software, geographic data and users. It also includes the methods designed for capturing, storing updating, manipulating, analysing, and displaying various forms of geographic data.GIS relates geographic locations on earth with the attribute information enabling consumers to visualize patterns understand relationships and trends. It is consisted of five key components which are hardware, software, data, people and procedures.

2.4 .1 Components of GIS

Figure 2 Components of GIS

Source (Scanners, Printer and Burner, 2002)

2.5 Access to health care

Health care is the provision of medical care to individuals and community.Acces to health care is one of the important principles of primary health care. It is the capacity of individuals to get care when they require it, regardless on one's capacity to pay for it,(Bissonnette, 2009). Numerous medical issues are preventable and curable through enhanced access to health care services. The creation of a satisfactory meaning of access is difficult since access is impacted by numerous factors.

Some researchers have characterized access as the capacity to utilize health care services and others contended that access is formed by variables influencing the utilization of health care services, ('Barriers Preventing Access To Health Care Services', 2005).(Discovery *et al.*, 2011) illustrated that access to health care implies having the timely utilization of individual health services in order to accomplish the best health outcomes. More over archiving good access to health care requires getting entry into health care system, having access to health care facility sites and finding suppliers who address the issues of individual patients and with whom patients can build up a relationship in view of common correspondence and trust.(Mcintyre and Ataguba, 2009) elaborated that access depend on the convenience, affordability and acceptability of health care services. Affordability concerns the level of fit between the full expenses of utilizing health care services and people's capacity to pay with regards to the family unit spending plan and different requests on that financial plan. Acceptability is much more about the fit among supplier and patient mentalities towards and desires for one another. However these definitions ignored the impact of the barriers of access.

However this study make use of the maximum demand a facility can serve and the total travel distance to optimally distribute health facilities in Gweru district so as to ensure access to health care. Moreover, according to (Kemboi and Waithaka, 2015) access to PHC requires heath facilities to be sited on suitable locations in order to deliver service to the population without travelling long distances. According to international standards set by WHO individuals should attain access to primary health care within a travel distance of 5km which is equivalent to 1 hour walking distance(Ofosu, 2012) . Population to provider ratio denotes the number health facilities present per a given population. Lower population to provider ratio is better measure of accessibility to health care facility than a higher population to provider ratio since it reduces waiting time

2.6 GIS in site selection

Optimal site selection is a procedure that asses areas of facilities depending on the predefined criteria. According to Ahmed *et al* (2016) site selection a decision-making process that requires numerous criteria to be weighted and choices to be assessed and positioned. GIS is best for health facility site selection problems since it is able to handle large amount of data and integrate various information from different levels of jurisdiction,(Phra *et al.*, 2006). In addition, the ability to make overlay functions gives GIS unique power to help in making decisions of determining optimal location for primary health facilities. The GIS database offers efficient and cost effective means of evaluating the best suitable sites for locating health facilities. With GIS technology it is easy to integrate and correlate information linked to the criteria considered in site selection.

2.7 GIS methods that have been used in health facility site selection

Researches have been done to define optimal location for PHCs utilizing different strategies.

2.7.1 Multicriteria evaluation analysis

Multi-criteria analysis is a method used to consider various criteria when making a decision and it gives a consistent procedure to follow so that different factors can be easily recognised. (Zhou and Wu, 2012) depicts multicriteria analysis as a methodology that coordinates differing criteria that are fundamental to be to be analysed in decision making. This approach allows the alternative solutions being considered to be ranked in order of suitability that is criteria are quantified according to their importance and significance. This can be done using the analytical hierarchy process and or the rank order method,(Neufville, 2013) . Analytical Hierarchy Process presented by Satty in 1980, is a method that assigns weights based on a hierarchical framework constructed through mathematical pairwise comparisons. The weights are deduced from the pairwise comparisons of the relative importance between each two criteria(Zhou and Wu, 2012).

GIS-based multicriteria analysis have been effectively used in various studies considering proper criteria and factors. In 2015 Wei and Ding used GIS-based multicriteria analysis in order to find suitable sites for residential areas.(Zhao, 2015) determined optimal location for sewage plant in china using multicriteria analysis and the results showed that optimal site was successfully selected. Another study by (Lin and Zu, 2013) used GIS-based multicriteria analysis for locating coffee shops in united states.

Researches using multicriteria analysis in the case of determining optimal location for primary health facilities include: (Ahmed, Mahmoud and Aly, 2016) developed a multicriteria decision support system for determining optimal location for hospital in Egypt through the integration of GIS and AHP. Factors were considered include Water and Air pollution, Green area coverage, accessibility in terms of time and distance means of transport type. Although results showed that optimal site was successfully selected, more factors should be considered. Population distribution should be considered as a factor as well.

A study conducted by Zhou and Wu in 2012 locate a suitable area for building another health facility in Haidian District of Beijing with the utilization of GIS-based Multi-Criteria Analysis. In order to use the multicriteria analysis many different factors were considered .Especially distance from residential and other criteria such as distance from existing hosipitals,rivers,public toilet and roads. In the final analysis necessity tests and sensitivity tests were carried out based on factor criteria using AHP and rank order method (ROM). Although an optimal hospital site was determined appropriate data should be used, in this study residential area data was used to represent population of which residential area data cannot accurately illustrate the population density of an area.

A study carried out by Chatterjee and Mukherjee in 2013 implemented a multi criteria evaluation of potential hospital sites in India using Fuzzy Analytical Hierarchy process (Chatterjee and Mukherjee, 2013).In this study cost, population characteristics and location were considered to be major factors .

(Ibrahim and Shouman, 2012) developed a model for determining best hospital location in Benghazi using multicriteria evaluation.(Youzi, Nemati and Emamgholi, 2018) addressed principles to be taken into consideration when selecting location for health centers.In their study they were aimed to optimize location of hospital in Kuhdasht city with the aid geographic information system integrated with analytical hierarchy process.

Furthermore another study aimed to assess the spatial distribution of primary health facility was introduce by Kibon and Ahmed,(Kibon and Ahmed, 2013).In their study they created a database for existing hospitals in order to evaluate the location and spatial distribution of primary health facilities in Kano Metropolis. From the results it was found that health facilities has been provided but they were not optimally located. In addition a similar study by (Ismaila, 2013) portrayed the application of geographic information system showing the spatial distribution and accessibility of health care services in Yola.

Although multicriteria evaluations are successfully used in in finding optimal location for health facilities, it has some limitations. (Comber *et al* 2011) argued that results from multicriteria analysis ignored the impact of demand in locating health facilities, locations are determined on the basis of their suitability using suitability index .In other words the findings describe the site where facilities could be located ignoring the impact of demand.

2.7.2 Location allocation models

Location allocation is a technique for determining optimal locations for facilities that provide services to the public, (Rahman and Smith, 2000). The location allocation models include the determination of the optimal sites of facilities from a set of candidate locations and in the meantime assigning demands to the intended sites effectively, basing on the spatial distribution of demands (Algharib, 2011). In other words the models simultaneously determine location of facilities and allocate population to facilities (Chang 2012). Location-allocation models seeks to determine best sites for facilities in terms of minimizing total distance or time for users thus location allocation models use different measurements based on travel distance, travel time and any other forms of cost function to determine best suitable locations. (Kemboi and Waithaka, 2015) illustrated that location allocation model contains a set of demand located at points ,the candidate locations for service facilities; a distance or time matrix holding distances or traveling time between facilities and demands locations.

According to (Daskin and Dean, 2004), the p-median model, maximum covering model and set covering model are the most location models utilised in health care.

P-median

The p-median model seeks to match supply and demand that is in a given set of demand. This model find the location of p facilities to minimize total weight of travel distance between demands and facilities(Buzai, 2013).According to (Engineering *et al.*, 2012) p median models seeks to locate a number of facilities and allocate demand to them in order to minimize total travel distance from demand to facility.(Mohammadi, Malek and Alesheikh, no date) portrayed that the mathematical formula for median is given as follows:

$$\text{Minimize} \sum \sum h_i \, d_{ij} Y_{ij}$$

$$\sum_j X_j = 1$$

$$\sum_j Y_{ij} = 1$$

$$Y_{ij} - X_j \leq 0$$

$$X_j \in \{0, 1\}$$

$$Y_j \in \{0, 1\}$$

Where h_i = demand at point i,

d_{ij} = distance between demand I and potential facility j

The disadvantage of these models is that individuals living in less accessible areas within the targeted region might travel long distances thus the solutions from this algorithm is biased since some users travel long distances (Meskarian *et al.*, 2017).

Maximal covering problems

These algorithms aims to maximize population coverage within a maximum service distance or time. Candidate facilities are located close to locations with high population density(Engineering *et al.*, 2012).According to (Buzai,2013) the objective function of maximal coverage models is to minimize demand within a coverage ratio.

Below is the formula for maximize covering:

$$\text{Maximize } \{F=\sum_{i\in I} a_i x_i\}$$

Where I= group of demand points

a_i= the population

<u>Set covering problem</u>

Set covering problems seeks to select suitable locations for facilities centres in order to minimize cost of demand (Mohammadi, Malek and Alesheikh, no date).These models locate facilities that cover all demand within a specified travel distance or time there by minimizing the number of facilities. Formulation for set covering models is as follows:

$$\text{Minimize } \sum_j c_j\, x_j$$

$$\sum_{j\in N_i} X_{j\geq 1}$$

$$X_j \in \{0,1\}$$

Where c_j = cost of locating a facility to a node

N_i=set of facility sites within an acceptable distance

The utilization of location allocation models to locate health facilities integrated with Geographic Information Systems (GIS) has become an essential tool for the decision making process (Menezes and Pizzolato, 2014). The application of location-allocation models in health care aim to improve the maximum amount of demands covered by equitable services that is maximizing the number of people allocated to each facility location and minimizing the total distance travelled to cover, and serve as many as possible in surrounding areas.

Location models have been broadly utilized in different studies trying to optimize site for facility locations so as to ensure universality in health care services. As portrayed by (Daskin and Din 2004) location allocation models have been utilized as decision support tools in health planning .(Rahman and Smith, 2000) carried out a study that aims to review the use of location allocation models in developing countries for health facility planning. In their study they provide a review of the use of location analysis to find set of optimal sites, location suitable sites in a new area, measuring the effectiveness of past location decision and finally improve existing location pattern in developing countries.

(Buzai, 2013) applied location allocation techniques to optimize primary health centres in the city of Lujan, Argentina. In this study the problem was solved as maximal covering location problem and the population centroids were treated as demand points as well as candidate facilities. In any case no mathematical formulation of the issue was given which would seem to be inappropriate. A similar study carried out by (Galvão, Espejo and Boffey, 2006) utilized location allocation models to locate maternal and prenatal health services in Rio. The objective was to distribute health care facilities in order reduce perinatal mortality in Rio.Their problem was maximal covering problem with facility capacity constraints. The model developed produced good distribution of perinatal facilities.

Furthermore another study carried out in Ecuador validate how location analysis could be applied in defining the optimal allocation of primary health facilities ,('Allocating Health Centers in a Resource - Constrained Setting in Ecuador', 2013).In this study the problem was expressed as a maximize coverage location problem and a maximize capacitated model was employed due to ability to model reality when the facility limit constraints are specified and it also allow to set distance threshold. The study achieved its goals and the results showed that location allocation models successfully allocate the health facilities efficiently in the most optimal areas closet to vulnerable areas. However it appeared that the total travel distance between demand and facilities were restrictively high therefore impedance cut-off should be considered. Indicating impedance cut off can minimize the travel distance between the population and the facilities.

(Comber *et al.*, 2011)developed a model for locating bioenergy facilities using GIS-based location allocation algorithims.The model developed in this study was an extension to p-median model. It took into account the spatial distribution of resources and their competition by facility locations. Furthermore another study carried out by Meyer in 2011 addressed the application of location allocation model in selecting optimal sites for fire stations in Toledo. The study seeks to increase safety and protection by improving efficiency of coverage based on minimizing the total travel time. A similar study introduced by Agharib in 2011 applied GIS and location allocation models to evaluate the spatial distribution of fire stations in Kuwait city in order to determine optimal location for new fire station and to analyse if the existing stations are optimally located to cover all demand (Algharib, 2011) .The study addressed the advantages of using location allocation model in site selection. Findings portrayed that the objectives were successfully met using allocation models.

Increasingly (Meskarian *et al.*, 2017) demonstrated how locational techniques can be successfully implemented to optimize sexual health services in Hampshire. The objective was to reduce number of facilities while improving access to service, hence they articulated the problem as maximal coverage problem. The problem was solved by greedy algorithim.The results from the algorithm showed that it required 25 facilities for full coverage. The results proved that under time constrained and resource scarce, one can accomplish great solutions utilizing greedy algorithm. However the new facilities selected by location allocation may not be worthwhile because of appropriate premises.

(Kemboi and Waithaka, 2015), in their study defined the utilization of GIS to improve geographic accessibility to health care services in Mt Elgon Sub-county. In their study finding optimal sites for locating health facilities was expressed as a maximal covering problem. The population centres were used as demand points, existing health facilities were used as facilities and a travel distance of five kilometres was set as the impedance cut off so as to show the population covered and not covered by the existing facilities in order to determine best locations that maximize the total number of people covered within the threshold of service distance.

The location allocation methods reviewed in this study have been planned as either p-median or maximal covering problems. The aim of p-median problem is to minimise travel distance between facilities and demand by locating a given number of facilities and the objective of maximal covering problem is to optimize a certain number of facilities so as to maximize demand within a recommended service distance. However most of the location models reviewed in literature depicted that the health facilities being located serve infinite demand which may cause congestion at the facilities. The researches focused only on the physical accessibility element of health coverage and not considering the other elements like availability. Availability is the number of health facilities per given population. Therefore not taking facility capacity into consideration may hinder accessibility to health service.

<u>ArcGIS network analyst</u>

According to(Menezes and Pizzolato, 2014) , ArcGIS network analyst extension provide the spatial analysis in a transportation network. This extension solve various problems like closest facility, service area and location allocation and there is a different solver for each problem. Regarding to heath facility location problem this tool permits the consideration of distances along the street networks. Increasingly(Kus, Cheu and Horak, 2016) portrayed that ArcGIS networks are grouped as geometric datasets and network datasets. Geometric data sets are intended for modelling waterways, river networks and utility network. The way is determined by external forces like gravity thus the movement in these datasets is permitted only in one direction. Network datasets were intended for modelling transportation network and as opposed to the geometric datasets, travel is permitted in both directions in the network dataset. Furthermore a network dataset must be appointed first in order to run any solver in a network analyst. A network datasets is consisted of the edges and connecting junctions. Utilizing these elements the genuine network is defined and they illustrate possible routes from one area to another (Resources ArcGIS, 2014).This study used this tool for analysis of primary health facility location problem.

<u>Location allocation models in ArcGIS</u>

According to (ESRI, 2012) ArcGIS support several location allocation models which are appropriate for locating primary health facilities and these are:

Table 1: Location allocation models in ArcGIS

Maximise coverage	Maximises the number of users covered within a specified distance.
Maximise capacitated coverage	Allocates a number of facilities with a finite capacity.
Minimise impedance	Minimise the total travel distance or cost of users
Minimise facilities	Find a minimum number of facilities within a specified distance.

The location allocation analysis solve location problems by applying the heuristic algorithm. The algorithm starts by utilizing the Dijkstra algorithm to generate the origin destination matrix of all the shortest routes between the demand and suitable facilities locations in the network.(Avery, 2014).

3 CHAPTER THREE

3.1 Methodology

This chapter seeks to give an outline of methods of data collection, data processing and analysis. This study applied GIS methods based on location allocation with the following objectives:

- To determine the theoretically optimal location for primary health care facilities in Gweru district.
- To evaluate if primary health care facilities in Gweru district are optimally located to serve the population

3.2 Study area

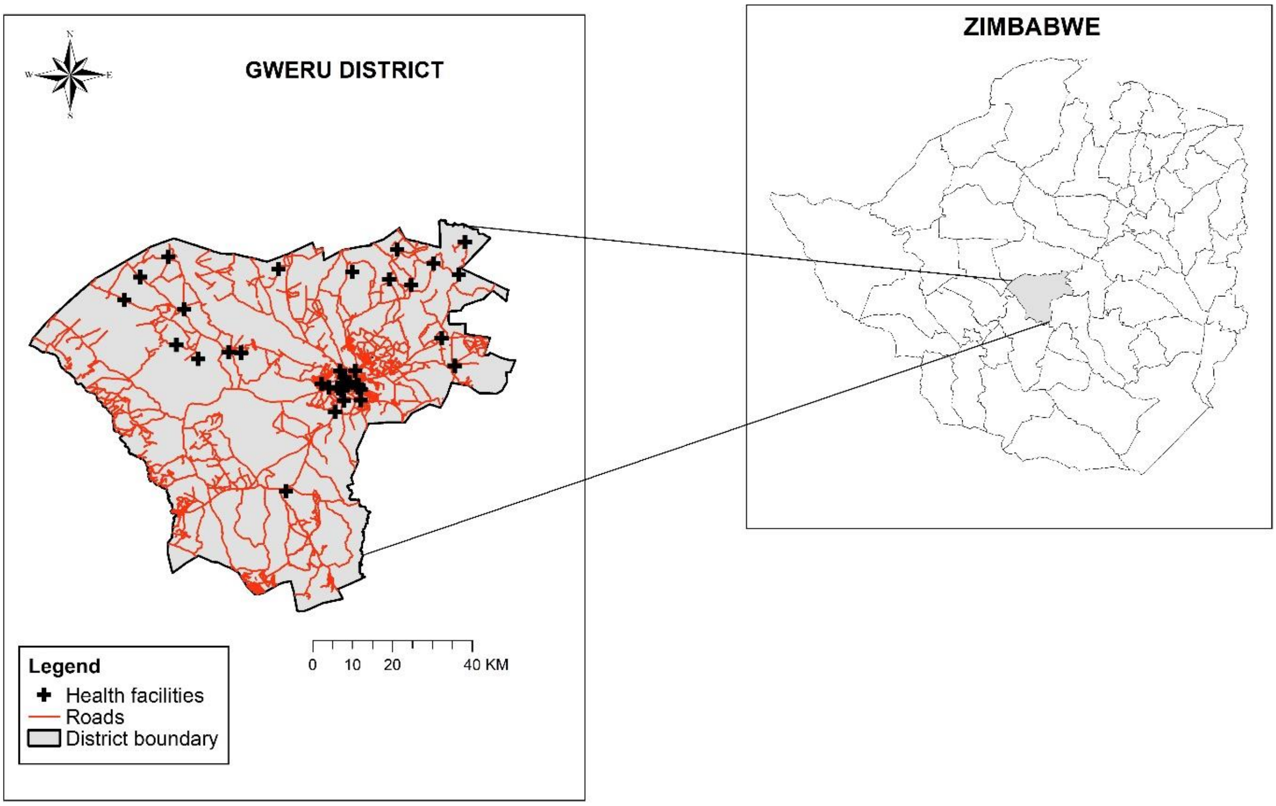


Figure 3 Study Area

Source: Author

Gweru district constitute of Gweru urban and Gweru rural .It is the capital of midlands province and it is located near the geographical centre of Zimbabwe. Gweru district had a population of 225139 according to 2002 census the population increased to 249671 in 2012

(ZimStats,2012).There are 37 health facilities in Gweru district with 10 being operated by Gweru city council. (ZimHealth strategic plan., 2016).

3.3 Data collection and data sources.

The researcher conducted an interview with Gweru municipality urban planner in order to get information on how they locate primary health facilities and also the parameters utilised in determining locations of these facilities in Zimbabwe.

The researcher made use of secondary datasets derived from various sources. These were comprised of road network, population distribution and locations of existing health facilities.

3.3.1 Population dataset

Population dataset was downloaded form World pop website (www.worldpop.org.uk). The dataset was obtained in raster format. It provide number of people per 100mx100m area. To determine the population distribution the raster population was converted to points using conversion tools in ArcGIS, and the vector points were extracted using extract values to points.

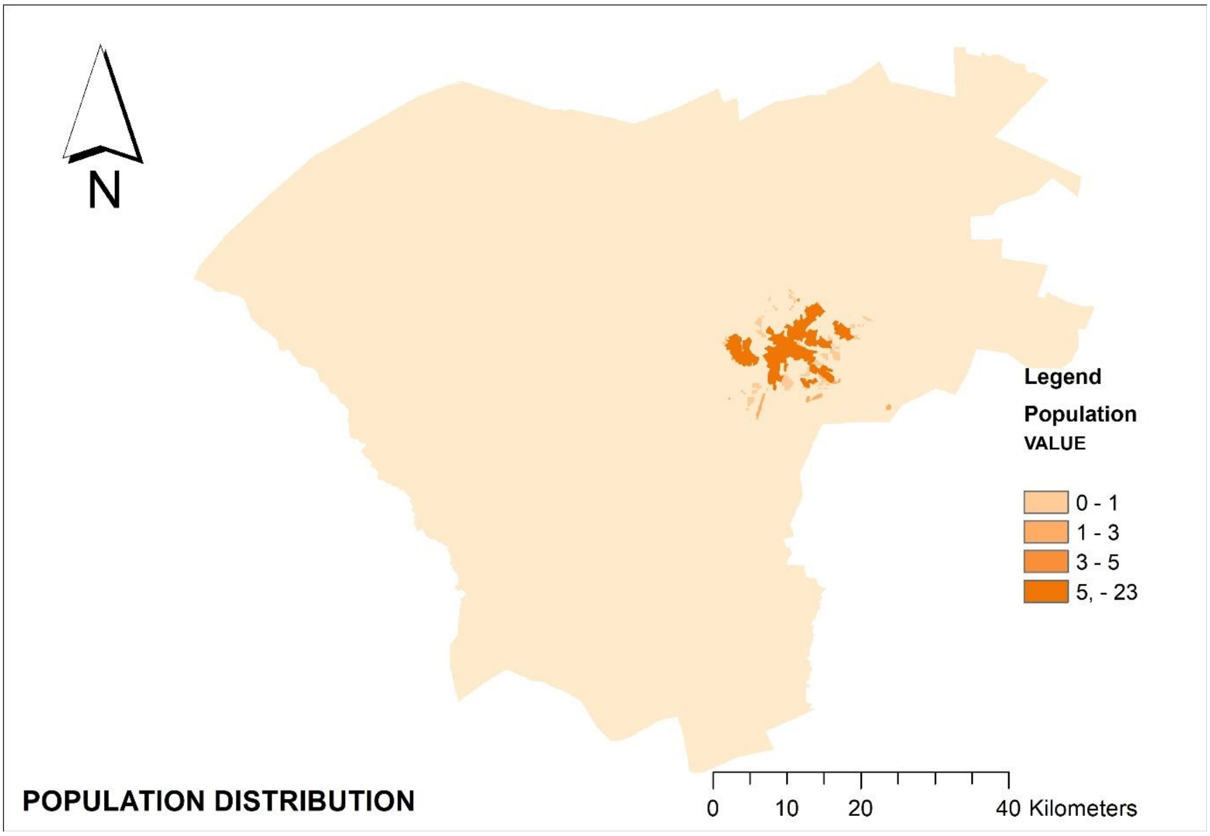


Figure 4 Population distribution

Source: Author population distribution

3.3.2 Health facilities

Health facility dataset was extracted from humanitarian data exchange, online database. The dataset provide GPS coordinates for primary health facilities in Gweru District.

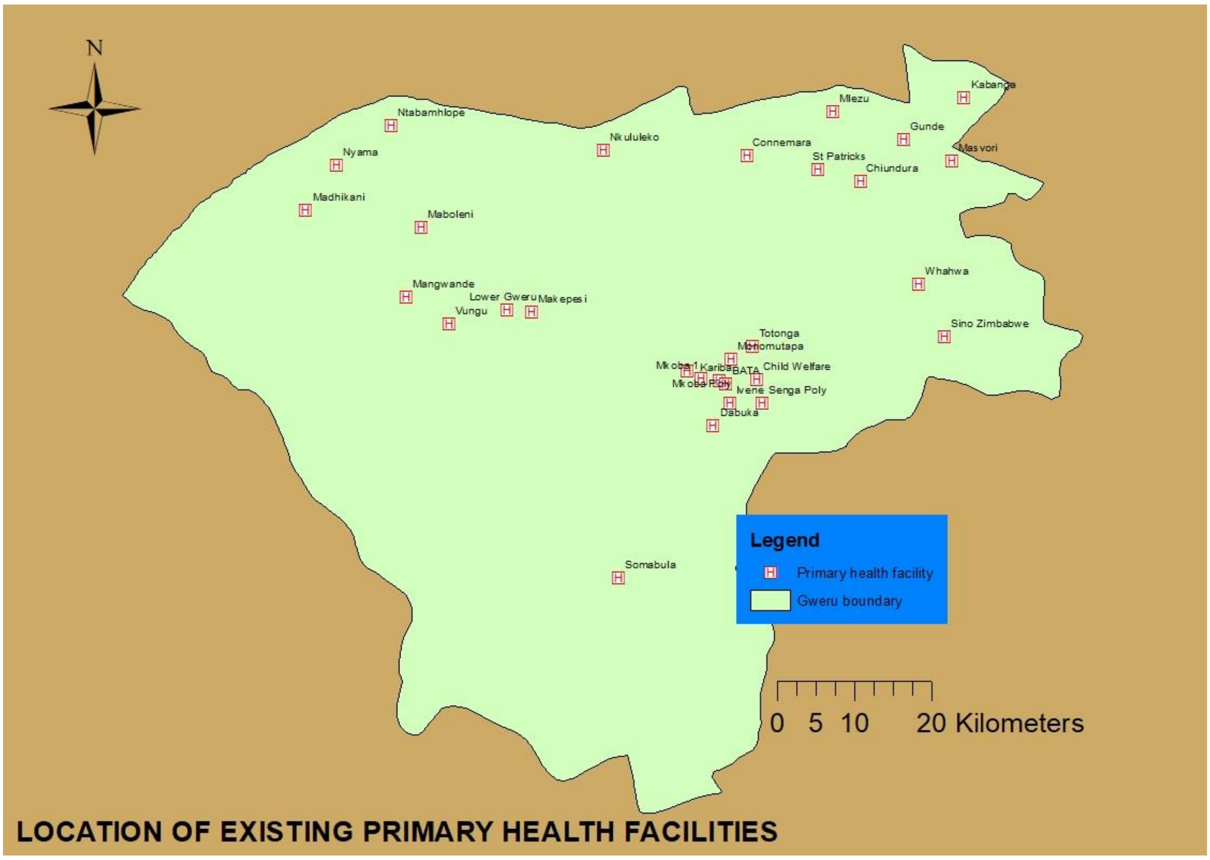


Figure 5 Location of existing primary health facilities

Source: Author

3.3.3 Road network

Road network dataset was downloaded from open street online database. The dataset consisted of only highways, major roads .The dataset was inadequate for this study since it only provide roads for the urban area and insufficient roads for the rural side of the district. The missing roads were filled by manual digitizing from high resolution google satellite base maps. The purpose of the road network was to link demand to facility by travelling through the network. According to (Avery, 2014), the road network should be linked and snapped together at the intersections to enable turns to be done during the analysis process. Here a road network topology was created to ensure that the roads are snapped and linked at the intersections. This was done by using the feature to line tool in ArcGIS.

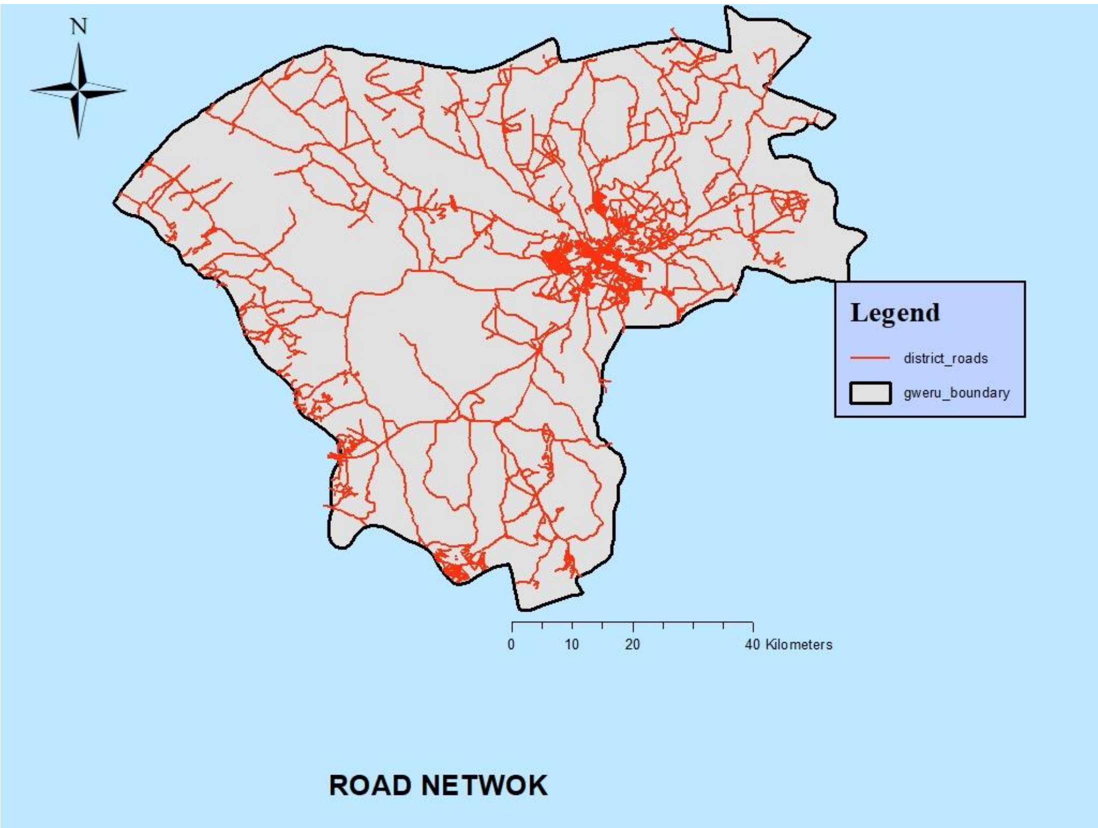


Figure 6 Road network

Source: Author

3.4Methodology structure

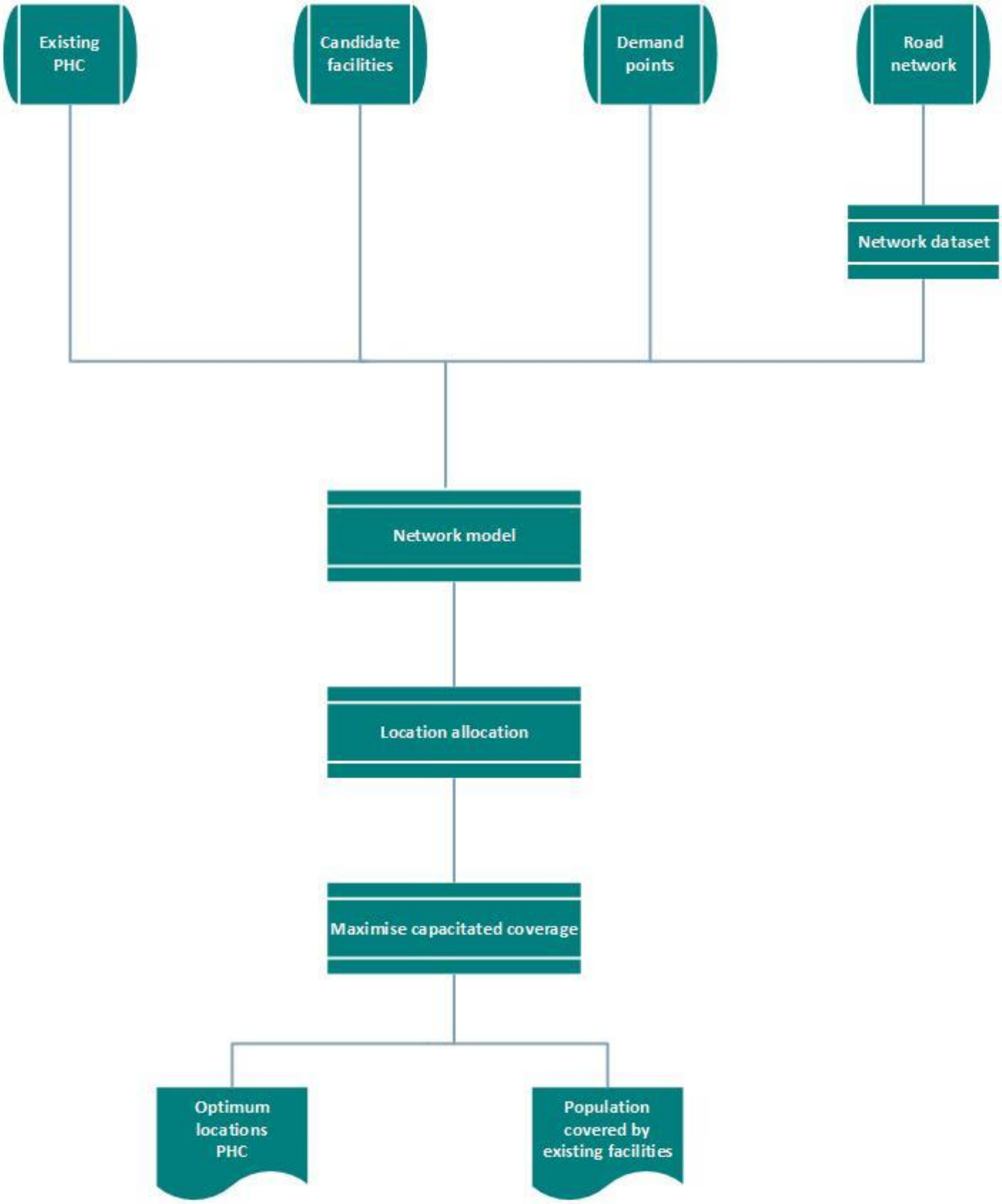


Figure 7 Flow diagram for methodology

Source: Author

3.4.1Establishing demand points

Population centroids were used as demand points .these centroids were established by converting the world pop raster population to points. Firstly the district was separated into urban and rural. The demand points for urban were established separately from those of the rural since the population densities of the urban and rural part of the district differ. For Gweru urban the raster population was aggregated by a factor of three so as to get 300m x300m population grids and for rural raster was aggregated by a factor of ten. The population grids were then converted to points and the points were then used to extract raster values to points in order to obtain weighted population points which represent grid centroids. There after the points for urban and rural were merged to obtain demand points for the district.

Process of establishing demand points

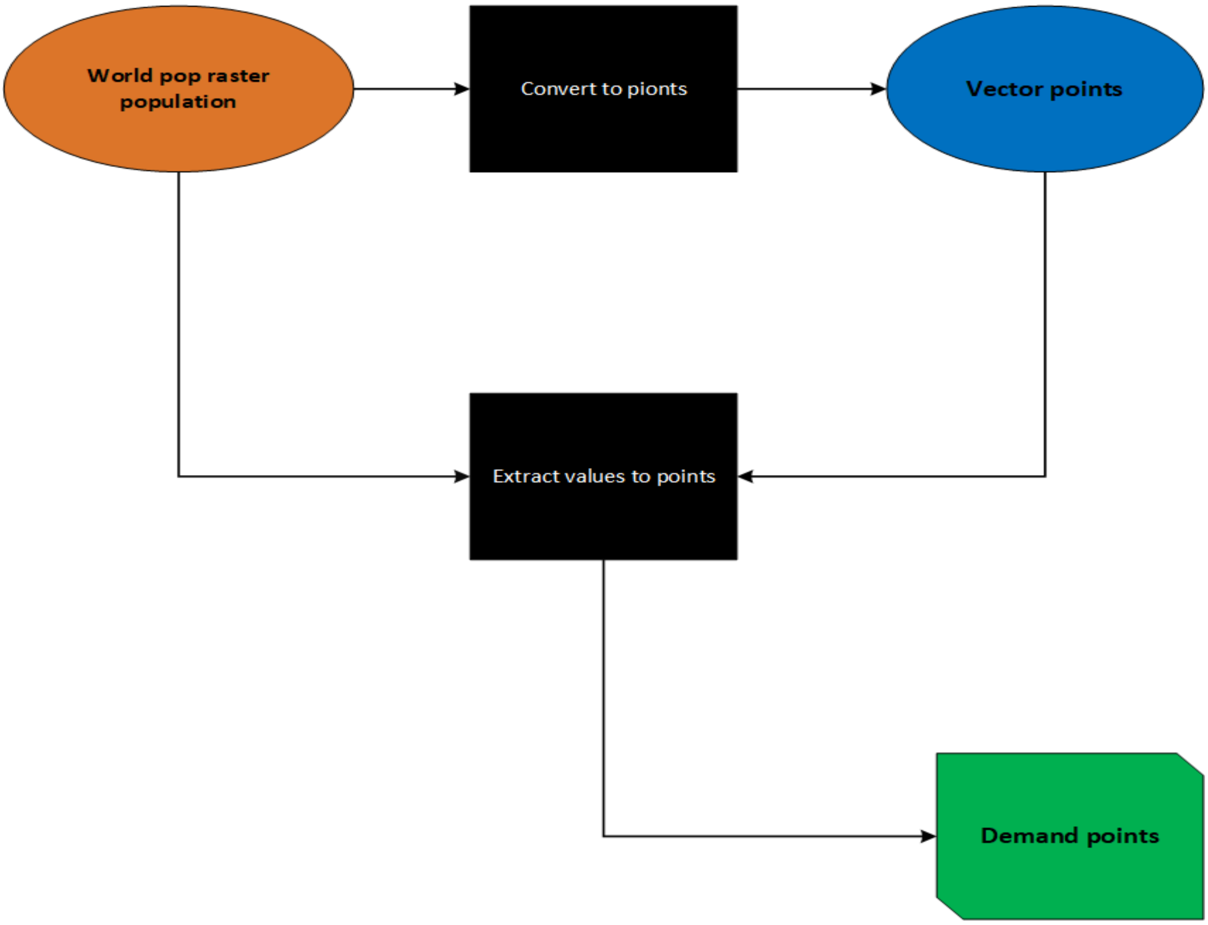


Figure 8 Methodology for establishing demand points

Source: Author

3.4.2 Establishing candidate points

Candidate points were obtained from fishnet grid so as to obtain evenly space points of the area. Two grids were created one for urban and the other for rural. The grid for urban was made at a cell size of 200m since urban area is densely populated and the one for rural has a cell size of 500m for the population in dispersed. The two grids were merged to obtained candidate facilities for the district.

3.4.3 Creation of network dataset for road

The network dataset was made by utilising road network data .Any junction on the road network which encompasses an intersection of links was assigned a node in the dataset. These nodes enable turns during analysis.

3.4.4 Creation of network model

After creating a network dataset the researcher build a network model using road network dataset, facilities and demand. This model show how demand is linked to facility through the exiting road network.

3.5 Location allocation analysis

In this study the problem of determining the optimal location for primary health facilities was expressed as a maximal covering problem and the maximise capacitated coverage model utilised because it maximises the number of people covered by a facility within a specified distance and also considers limit of a facility. With this model demand was allocated to the closest facility and along these lines if the closest facility achieved its ability limit demand was then allocated to the second closest facility and so on.

3.6 Location allocation process.

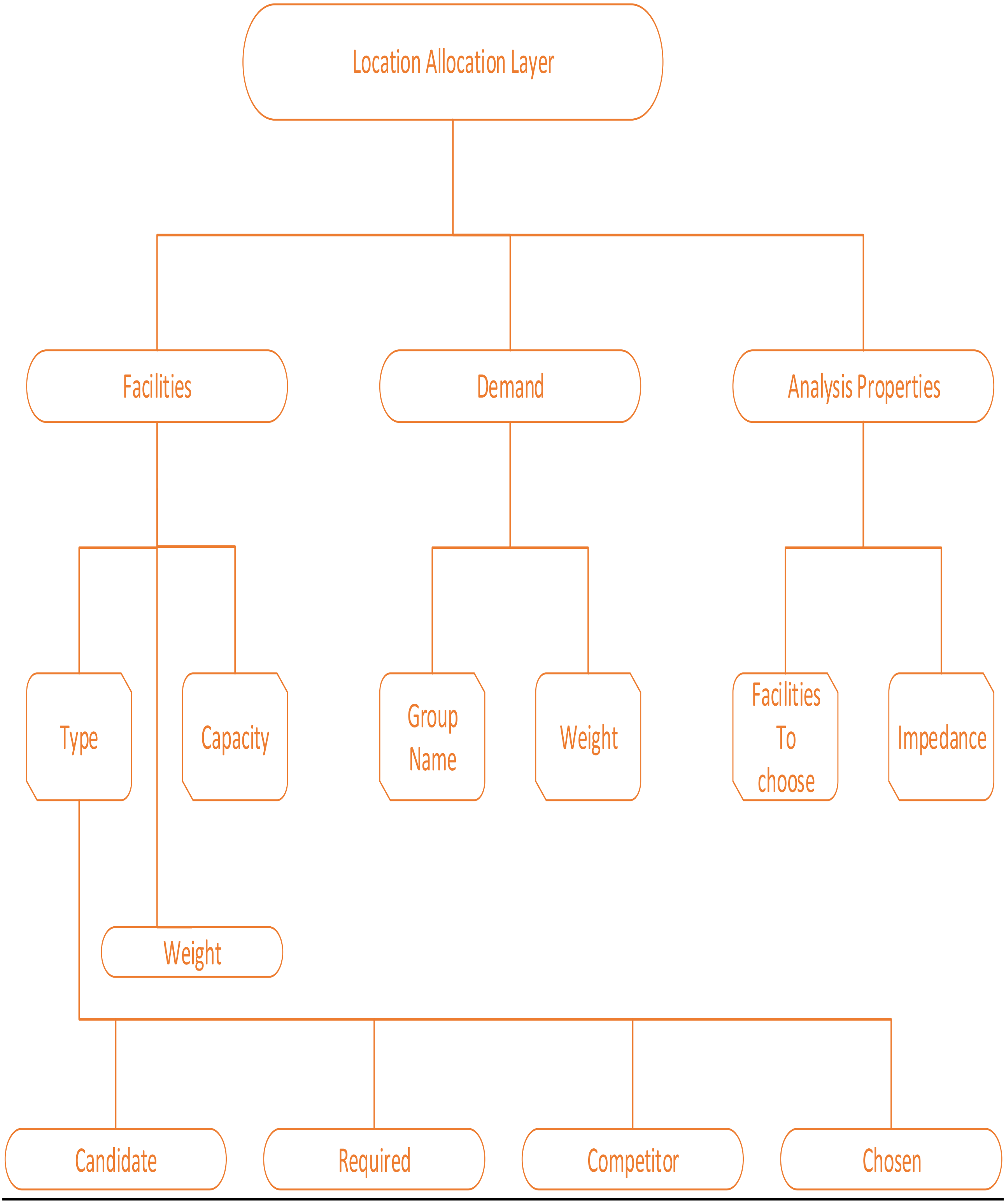


Figure 9 location allocation process

Facilities

These can be represented candidate, required competitor and chosen facilities. Here facilities were represented by candidate facilities. These were candidate points obtained from fishnet grid and these were the possible potential sites for locating primary health facilities.

The properties of facility incorporates weight and capacity. In this study the facilities had a default weight of 1.0 since they are similarly important in serving the population. Each facility has capacity of serving 10000 people.

Demand

Demand points represent the population that need health services from the facilities. In this study demand points are weighted population points extracted from the world pop grid population. Demand weight is the amount of people that require service from a facility, in this case demand weight was represented as the population per point which is the number of people per grid.

Analysis properties

Facilities to choose and impedance cut of are the essential properties of the analysis parameters. Here 28 facilities were selected and below is the mathematical formula utilized to obtain the number of facilities to choose.

$$\text{Facilities to choose} = \frac{population}{facility\ capacity}$$

Then a recommended travel distance of 5km from demand to facility was set as an impedance cut off and the direction of travel was set from demand to facility. Finally the location allocation model was executed to determine the optimal locations for primary health care facilities.

In summary the researcher conducted a network analysis by clicking on new location allocation then on network analyst window click on facilities move on to load facilities and these facilities were the evenly distributed points obtained from fishnet which represent potential sites for locating primary health care facilities. In the facility tab the researcher selected candidate as facility type and accepted default since all facilities has similar importance on serving demand. Next demand points were loaded which in this study were population points. After loading facilities and demand it was required to set some location allocation specifications, in the analysis settings the travel from demand to facility was selected since people travel from their homes to facilities in order to seek health care services. Under the advanced settings the problem type was selected as maximize capacitated coverage because it maximizes a finite demand which required heath care services within a specified distance. Maximize capacitated model minimizes the travel distance between demand facilities by assigning a fixed number of health facilities with a restricted capacity. Under the facilities to choose 28 facilities were chosen which were obtained from dividing the total demand by the facility capacity. According to WHO the number of health facilities per 10 000 population is the recommended core indicator to assess facility capacity which in this case facility capacity was set to 10 000.Then the impedance cut off which in this case represent the travel distance from demand to facility was set to 5km which is the international standard travel distance recommended by WHO. The location allocation problem was then solved to determine the optimal sites of primary health facilities. Since the population in rural areas is dispersed and also some people who reside in low-density areas can drive or use other means of transport to PHCs another model with an impedance cut off of 10 km was developed to increase accessibility.

3.7 Evaluation of the location of existing primary health facilities

To evaluate if the existing facilities are optimally located to serve the populations, the researcher identified the accessibility to existing primary health facilities through the road network by generating service areas within a distance 5km from the facilities. In the present study the researcher determined the catchment areas within 5km of each facility through points that are located 5km from the facility through the road network. The researcher conducted a new location allocation. Facilities were loaded and in this case facility type was selected as required and default was accepted. The demand points were also loaded and after loading these two the researcher set the location allocation parameters .The problem was formulated as maximize capacitated coverage, a facility limit of 10 000 and 5km travel distance was also specified. The problem was solved and catchment areas covered by existing facilities were defined. The population served by the existing facilities within the specified thresh hold was determined and also the spatial accessibility of the existing facilities was measured. Catchment area within distance of 10km(double the recommended) were also established to find served and underserved population considering that people may travel to

PHCs using other means of transport than walking and also that the population in rural areas live in scatter settlements.

SA = (population covered within the catchment area * total population) * 100%

Comparing the existing locations with the optimal

The catchment area analysis results for the whole district were compared with the optimal. The population served by the existing facilities within the recommended distance was calculated and compared with the population served by the optimal.

CHARPTER FOUR

4 RESULTS AND DISCUSION

This chapter presents the findings of the analysis in this study based upon the methodologies in addressed in the previous chapter.

The fig 10 below show the demand points obtained from converting the raster population to points.

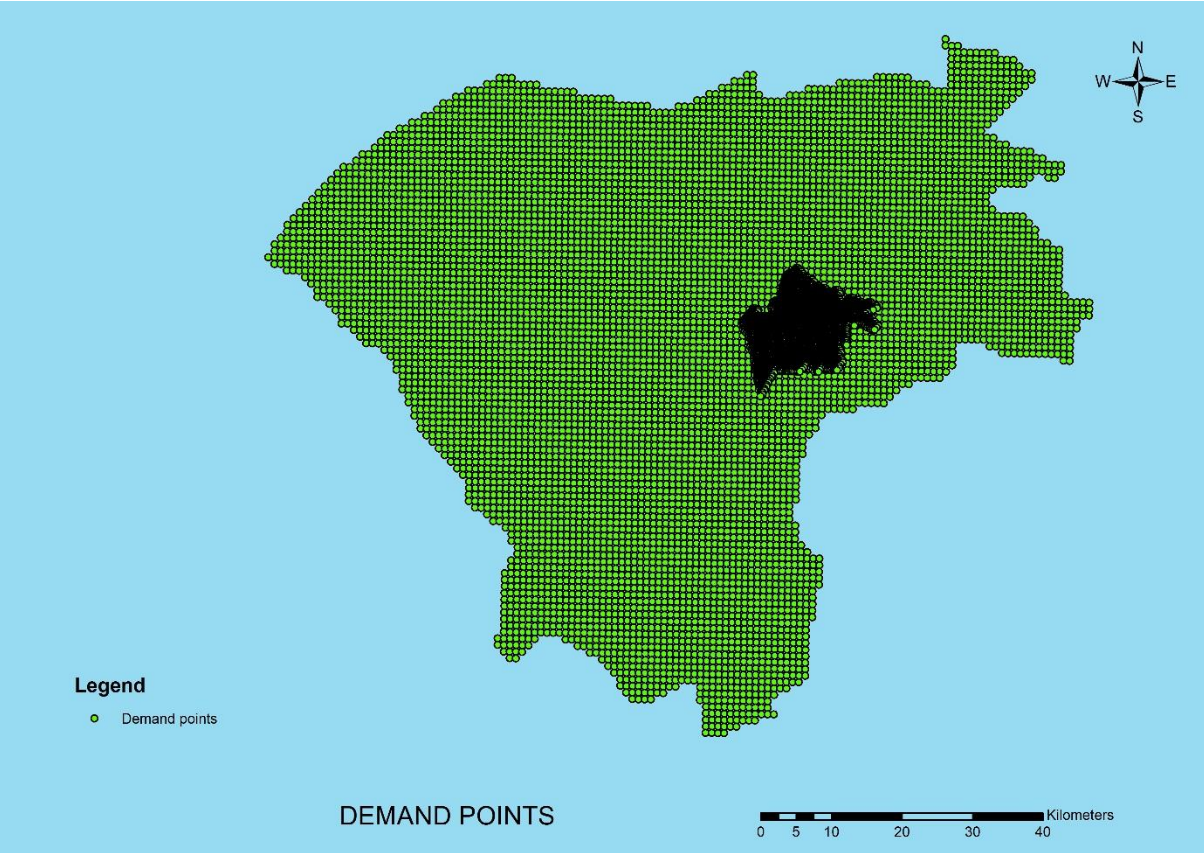


Figure 10 Demand points

Results of the candidate points

The fig 11 below show the results of candidate points obtained from fishnet grid

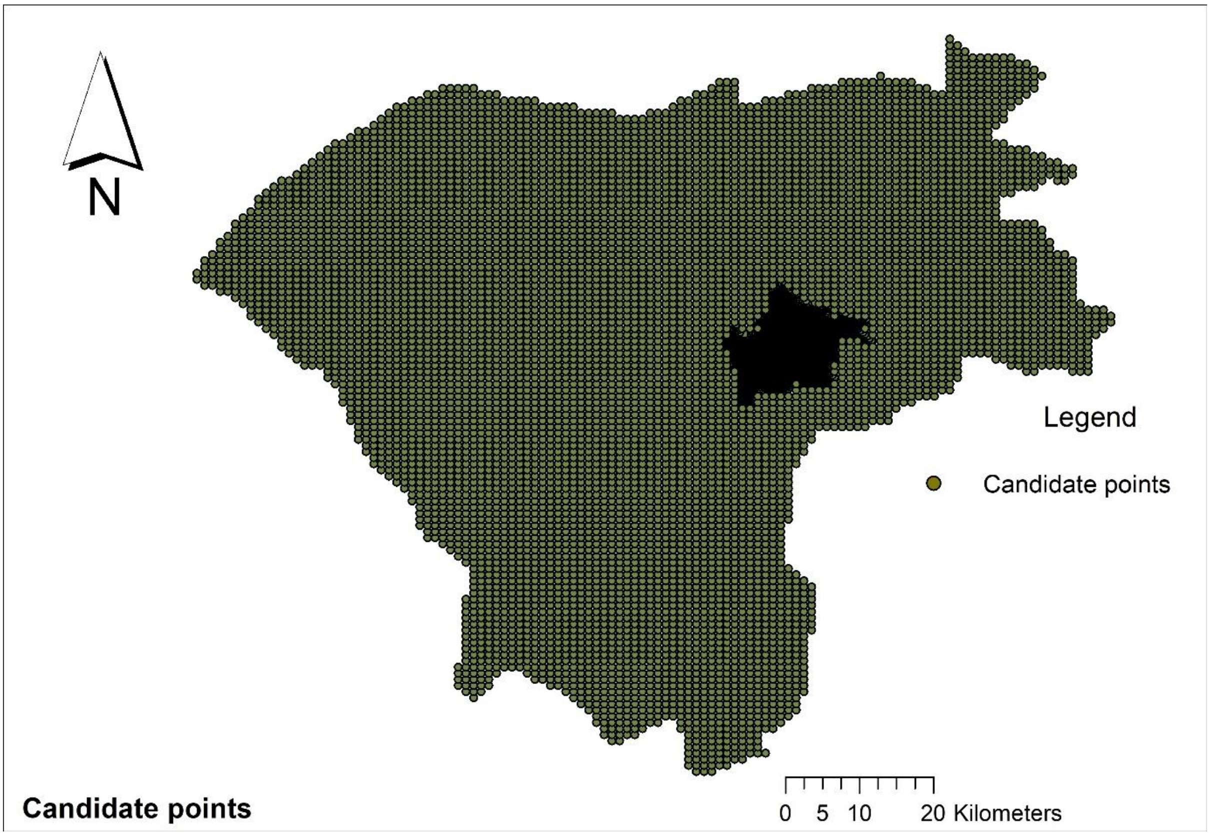


Figure 11 Candidate points

Results of the network dataset created

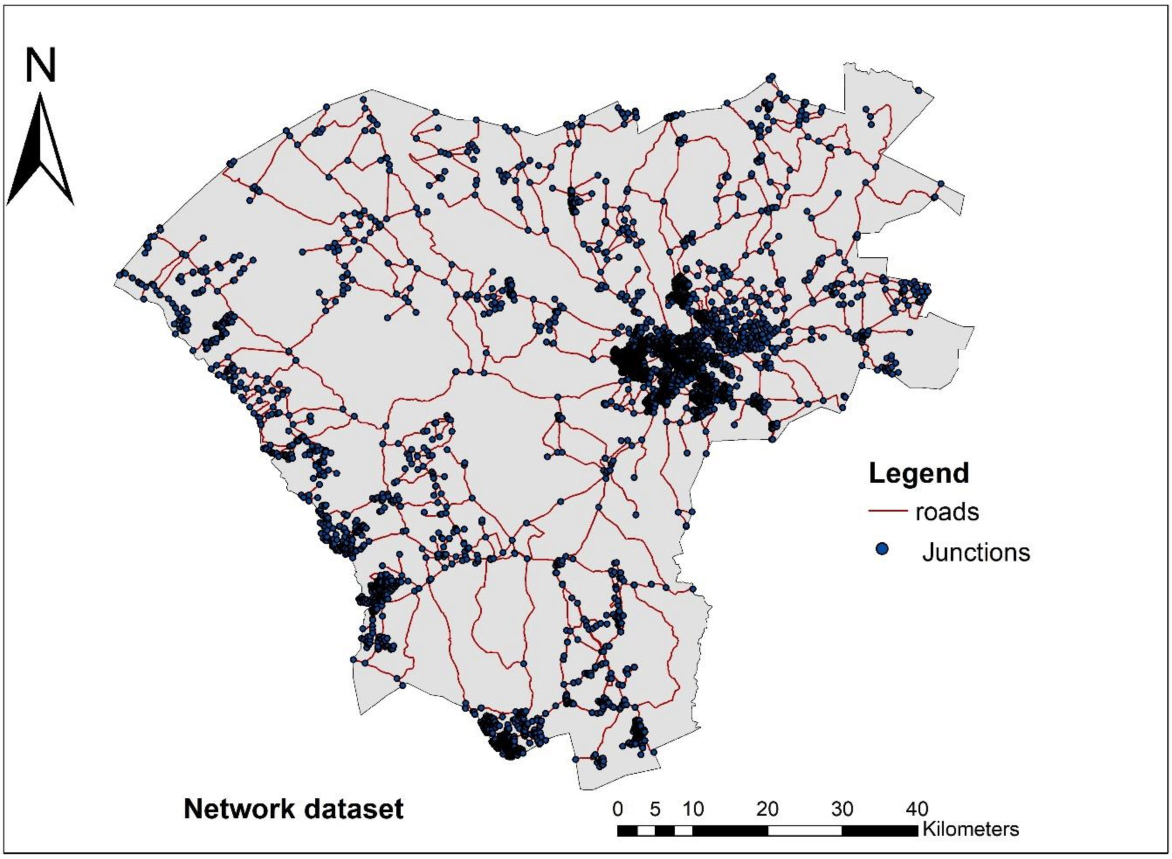


Figure 12 Network dataset

After a network data set was developed it was followed by building the network model that link the demand with the facilities through the road. Below is the structure of the network model developed.

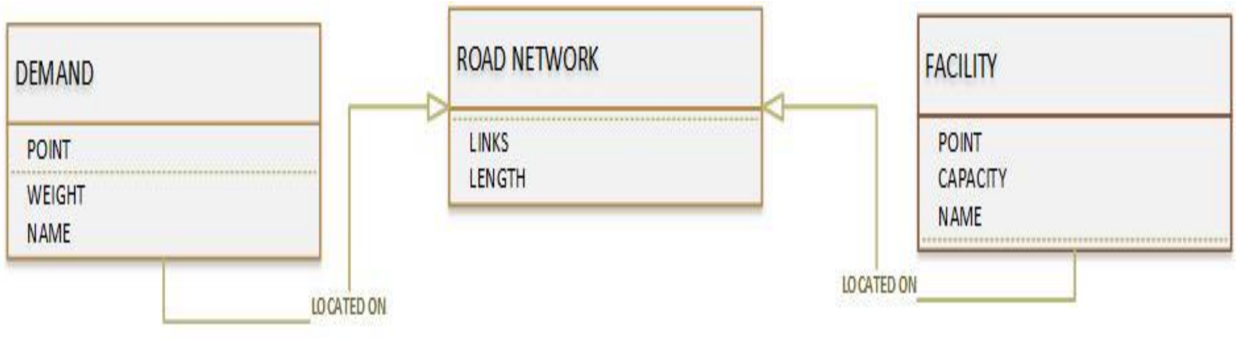


Figure 13 Network model

4.1 Theoretical optimal location of PHCs

In this study the first objective discussed in the methodology is determining the theoretical optimal locations for primary health facilities in Gweru district. The researcher applied maximize capacitated coverage location allocation model. The analysis allocate demand to the nearest facility and along these lines if the nearest facility achieved its ability limit demand was then allocated to the second closest facility and so on till all the demand points are allocated to the facilities. Fig (14) shows the results of maximize capacitated coverage model with impedance of 10km distance. The map shows the theoretical optimal locations of PHCs in Gweru district.

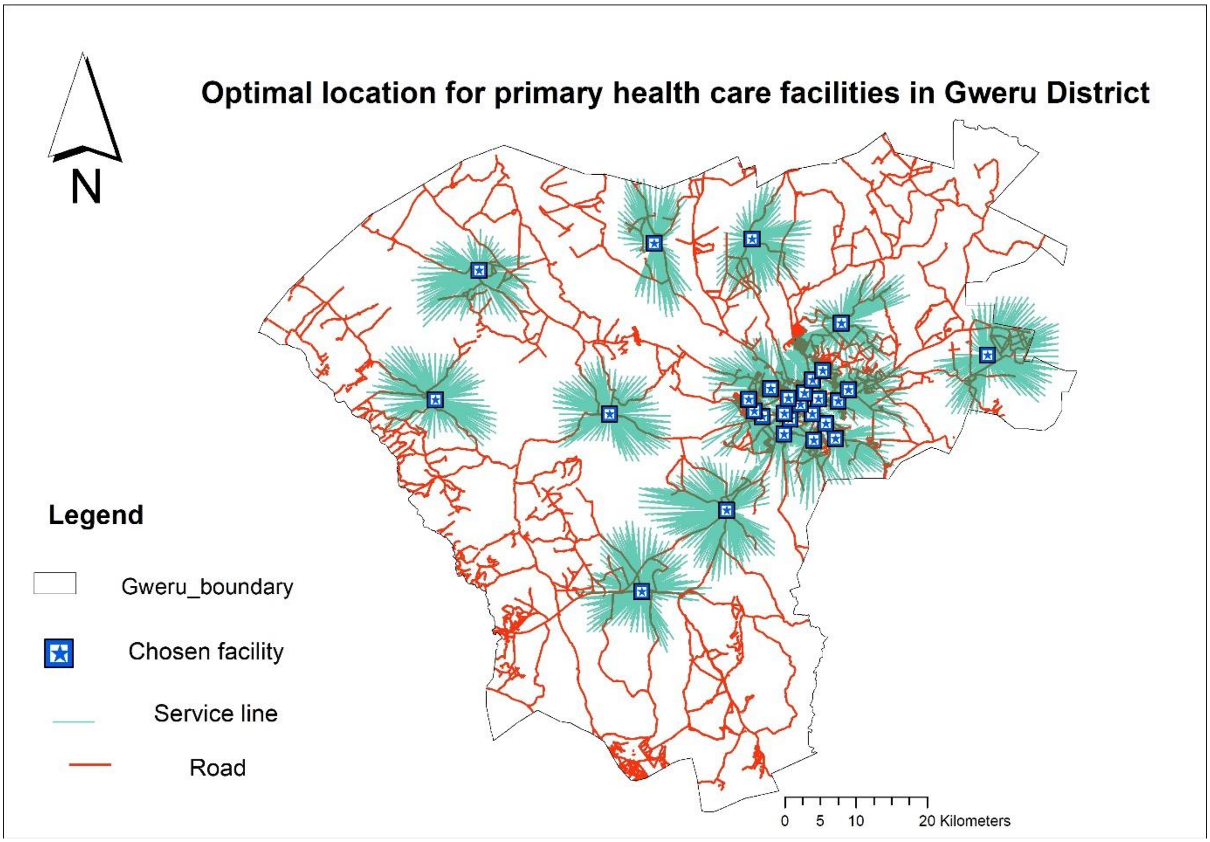


Figure 14 Location allocation using impedance of 10km

From the location allocation model a total of twenty –eight health facilities were allocated each having a capacity of 10 000 demand. Analysing the accessibility of the allocation 68% of the population has access to primary health facilities within a travel distance of 5km and a facility capacity of 10 000, that is only 18846 people are served out of a total population of 277155 . This means that 32% of the population which is 88689 people access the facilities by traveling a distance which is more than 5km from demand to facility. Facilities in rural areas did not reach their capacity within the 5km distance this is because rural areas are sparsely thus they live in scatter and leap frogging settlements. Also there is high accessibility in the urban area, facilities reach their capacity in a travel distance less than 5km.In urban area people are densely populated on a small area they live in poly- nucleated settlements. Most of the primary health facilities are located in or near the city centre and most of the population residing in Gweru urban are able to access these facilities within the recommended distance. Increasing the impedance cut off by double the recommended travel distance increases accessibility by 8%.Table 1 show the number of people covered within the recommended distance.

Table1: Demand covered within 5km distance with capacity constraint of 10000

FacilityType	DemandWeight	Total_Length	TotalWeighted_Length
Chosen	6233	305195,3654	10173251,34
Chosen	10000	260601,1206	14088594,78
Chosen	8676	160731,7172	9855357,241
Chosen	8876	162218,5682	12409561,03
Chosen	9956	136933,9042	11936771,55
Chosen	10000	231910,103	9739610,834
Chosen	9975	167429,135	10162416,11
Chosen	9999	84636,14536	10766920,57
Chosen	10000	140361,0788	11769658,86
Chosen	9929	48052,98428	9099435,786
Chosen	9999	183793,7827	11427253,44
Chosen	7231	275185,6772	13341953,44
Chosen	9988	187757,238	9726331,458
Chosen	9972	89692,003	10170547,21
Chosen	9944	79028,64535	9951036,622
Chosen	10000	231810,3549	12453412,99
Chosen	10000	256620,7042	11847547,64
Chosen	3024	387664,895	6340522,42
Chosen	9999	244661,0076	10435707,45
Chosen	2701	309272,2165	5485655,012
Chosen	1980	450278,377	5692351,381
Chosen	1464	294385,237	3851509,345
Chosen	1467	317082,0031	3567445,244
Chosen	1330	270384,6792	4084117,924
Chosen	1903	170547,011	5778357,707
Chosen	1400	262418,0967	3710493,073
Chosen	1359	369544,9847	5002405,563
Chosen	1680	298214,1848	4996889,453

Table 2: Location allocation model using 10000 as facility capacity and 10km travel distance

FacilityType	DemandWeight(population)	Total distance(km)	TotalWeighted distance(km)		
Chosen	7578	702636,5057	15761828,52		
Chosen	8286	621039,9729	16934717,71		
Chosen	10000	356031,7	16271243,84		
Chosen	9994	172905,9216	14142209,22		
Chosen	10000	195839,0942	12095125,18		
Chosen	10000	544541,3939	11416366,24		
Chosen	10000	226368,8695	10066355,88		
Chosen	9999	126594,5209	10813477,8		
Chosen	10000	206222,354	11424752,16		
Chosen	9998	132987,9275	9408596,346		
Chosen	10000	226032,7442	11281336,69		
Chosen	9803	1606148,054	27104759,22		
Chosen	10000	180351,79	10860369,75		
Chosen	10000	169893,184	10840835,72		
Chosen	10000	122769,7035	11058272,78		
Chosen	7374	1409950,02	27357964,13		
Chosen	10000	344143,3789	14535964,9		
Chosen	10000	247212,5629	11911024,94		
Chosen	10000	209339,5607	10768792,41		
Chosen	3898	1665441,891	25174002,06		
Chosen	4046	1952152,959	28129856,68		
Chosen	3210	1349702,922	18276294,34		
Chosen	3213	1438427,964	19648264,71		
Chosen	3340	1862189,603	23757650,7		
Chosen	2588	1467266,444	16167817,24		
Chosen	3424	1484540,787	22418985,26		
Chosen	2937	1159351,208	19571212,06		
Chosen	2736	1268261,426	17690421,99		

Separate models were developed for rural and urban to see the accessibility of health facilities. In Gweru urban there is a population of 174554 according to world pop statistics and 97% of the population have access to health facilities within 5km travel distance. Fig 15 displays the optimal location of PHCs in Gweru urban district. The map also shows the distance classes which display the distances travelled from demand to facility.

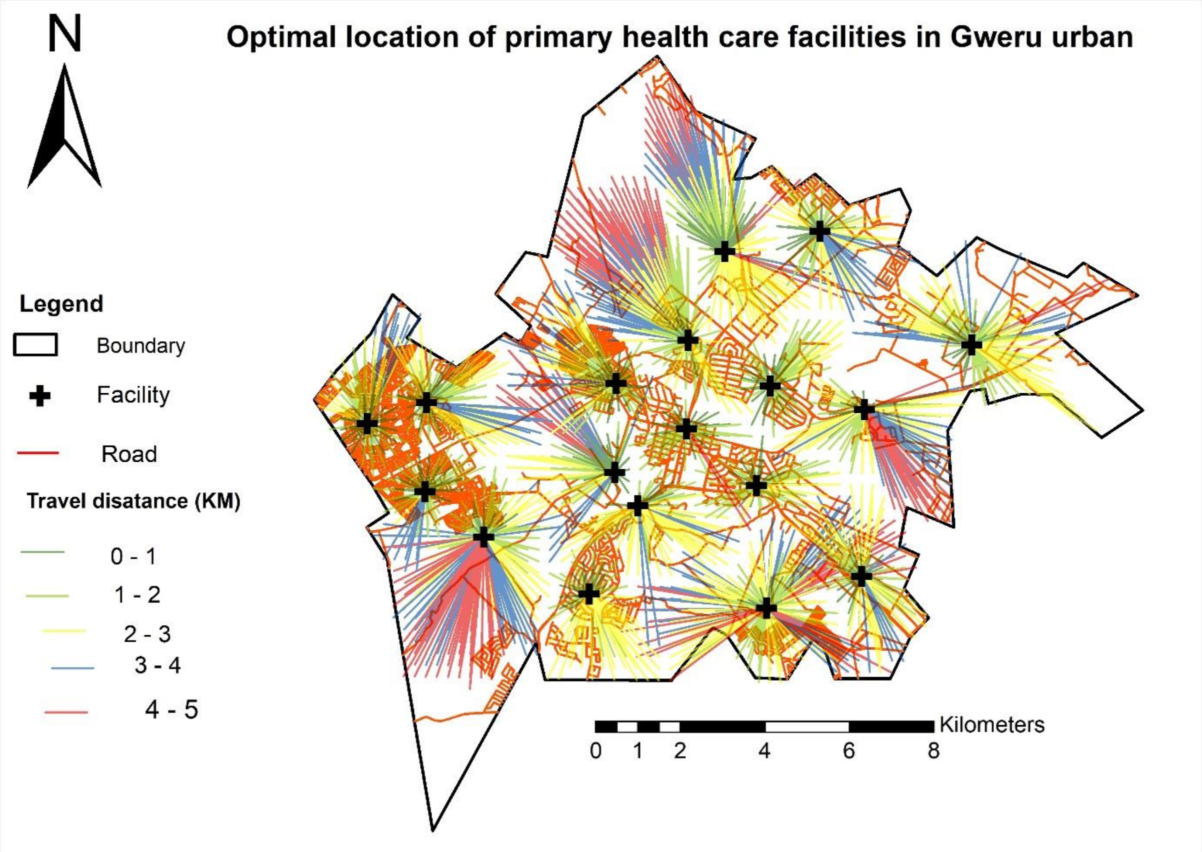


Figure 15 optimal location of PHCs in Gweru Urban

Fig 16 is a map that shows the optimal location of PHCs in Gweru rural district. It also show the varying distance travelled from demand to facility .People in rural areas travel long distances to health facilities due to poor road network. From the maps it is clearly shown that there is good access to health care in the city and poor access in rural.97% of the urban population access health facilities within the recommended distance of 5km and only 14% of the rural area have access to care within the standard distance. More facilities had been located on more dense areas of the district. This shows that facilities are located with respect to population growth. For example Mkoba is a high dense residential area and it can be seen that there is high concentration of primary health facilities in Mkoba.

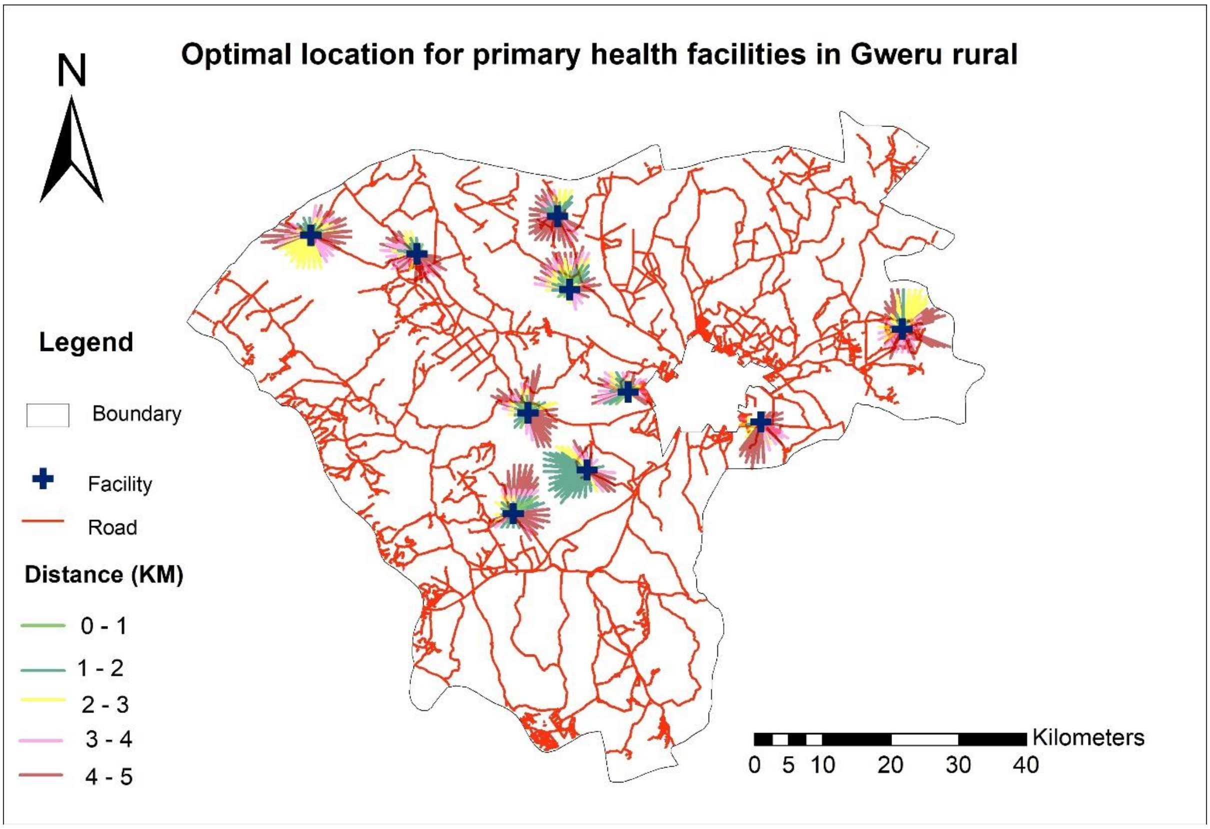


Figure 16 Optimal location of PHCs in Gweru rural

4.2 Evaluation of the location of existing primary health facilities

Fig 17 present the population served by the existing primary health facilities within a travel distance of 5km as recommended by WHO. Demand allocation is determined through the real road network though the lines shown do not trace the actual route taken through the network.

Table 3 provides results of the number of people served by each of the existing primary health facilities within 5km.These results seem to show that the existing facilities are not optimally located to serve demand. Only 37% of the population can access the existing facilities within the recommended distance. This result depict that people walk more than 5km to access the health facilities

Map showing population served by existing facilities considering capacity and distance threshold.

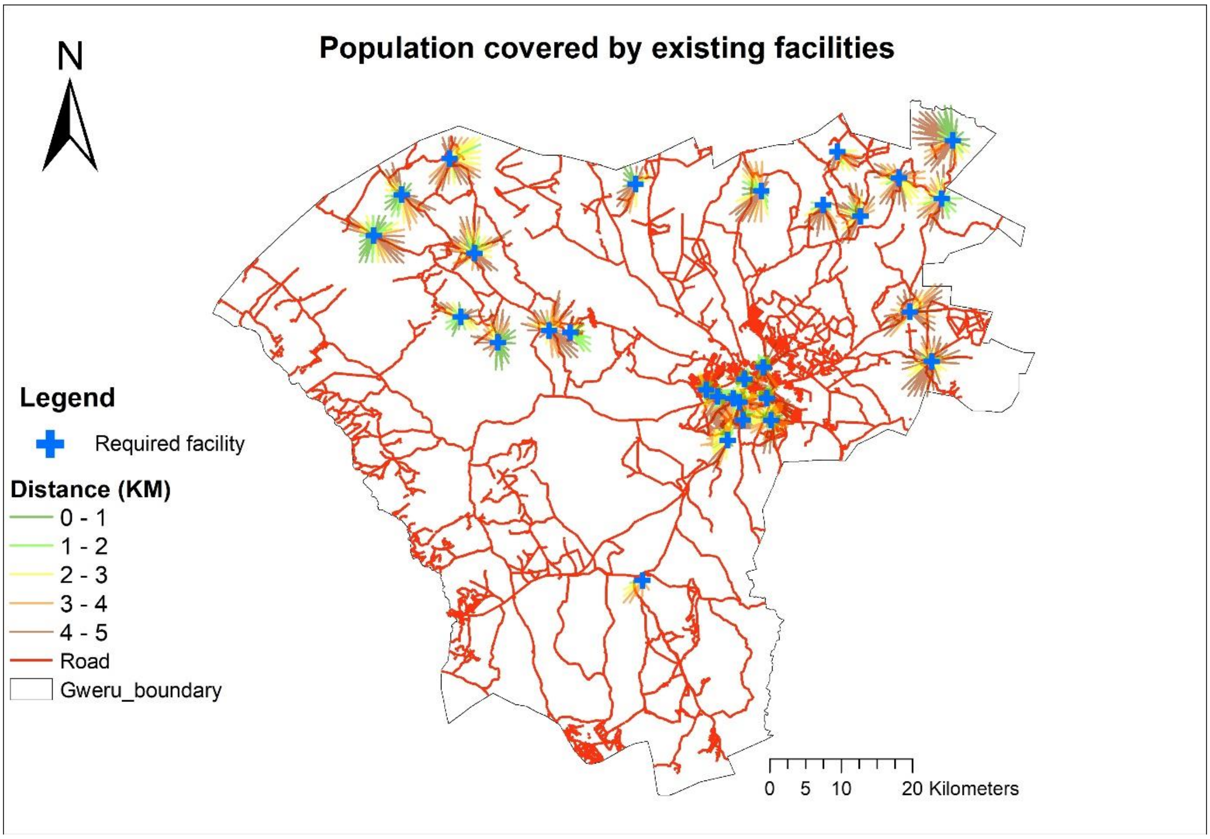


Figure 17 Service area for existing facilities

Table 3: Location allocation model using 10000 as facility capacity and 5km travel distance as impedance existing primary health care facilities.

	Name	FacilityType	DemandWeight (populati	Total distance travelled(km)	TotalWeighted dist (km
	Chiundura	Required	143	119247,2071	455878,2601
	Connemara	Required	754	134613,9955	1883152,227
	Gunde	Required	315	152033,0818	1006037,775
	Kabanga	Required	1136	180276,4629	2976405,076
	Lower Gweru	Required	487	178646,5666	1536718,796
	Maboleni	Required	689	191776,1723	2310412,248
	Madhikani	Required	1347	138566,8444	3126778,49
	Makepesi	Required	104	34475,99033	218313,7534
	Mangwande	Required	156	69286,61024	291892,2922
	Vungu	Required	542	96208,09269	1023240,826
	Whahwa	Required	614	196182,6926	2140796,623
	Masvori	Required	561	108004,0707	1424606,934
	Mlezu	Required	108	55676,9048	235536,3861
	Nkululeko	Required	516	68549,33826	1135022,354
	Ntabamhlope	Required	248	168845,9861	722730,6252
	Somabula	Required	137	34328,52768	311086,0121
	St Patricks	Required	241	71030,40518	566280,626
	Dabuka	Required	1844	511991,1375	4598658,568
	Kariba	Required	10000	190980,4029	14665929,56
	Ivene	Required	9900	269844,2937	23982712,17
	Totonga	Required	10000	97261,6629	11483436,91
	Monomutapa	Required	10000	80407,96455	11120717,04
	Child Welfare	Required	10000	95966,53018	11194143,85
	Senga Poly	Required	10000	467437,8341	20388474,69
	Mkoba Poly	Required	10000	77030,66352	10271467,59
	Sino Zimbabwe	Required	902	232882,6744	3061301,453
	Nyama	Required	547	117308,4735	1189245,202
	Mkoba 1	Required	10000	102480,8456	10551048,96
	BATA	Required	10000	201200,6555	16344901,91

From the population covered within 5km facilities located in rural areas serve less demand than those in urban probably because there is poor road network in rural. Since location allocation models allocate demand to the facilities using road network. Additionally the demand of Gweru rural is not high and is dispersed. By increasing the travelling distance to 10km population served by existing facilities increased from 102542 to121948 people. Table4 show the population covered by existing facilities within 10km.Facilities located in the central part of the district attain their capacity within a distance less than 5km because there is high population density.

Table4: population covered by existing facilities within 10km

Name	FacilityType	DemandWeight	
Chiundura	Required	427	
Connemara	Required	2088	
Gunde	Required	580	
Kabanga	Required	1136	
Lower Gweru	Required	1887	
Maboleni	Required	1612	
Madhikani	Required	2850	
Makepesi	Required	689	
Mangwande	Required	512	
Vungu	Required	1098	
Whahwa	Required	2113	
Masvori	Required	1111	
Mlezu	Required	835	
Nkululeko	Required	1444	
Ntabamhlope	Required	413	
Somabula	Required	137	
St Patricks	Required	775	
Dabuka	Required	10000	
Kariba	Required	10000	
Ivene	Required	10000	
Totonga	Required	10000	
Monomutapa	Required	10000	
Child Welfare	Required	10000	
Senga Poly	Required	10000	
Mkoba Poly	Required	10000	
Sino Zimbabwe	Required	2073	
Nyama	Required	1310	
Mkoba 1	Required	10000	

Table 5 illustrates the number of people served by existing facilities considering that all people are allocated to the nearest facility within 5km irrespective of capacity.

Table 5: population served by existing facilities irrespective of distance

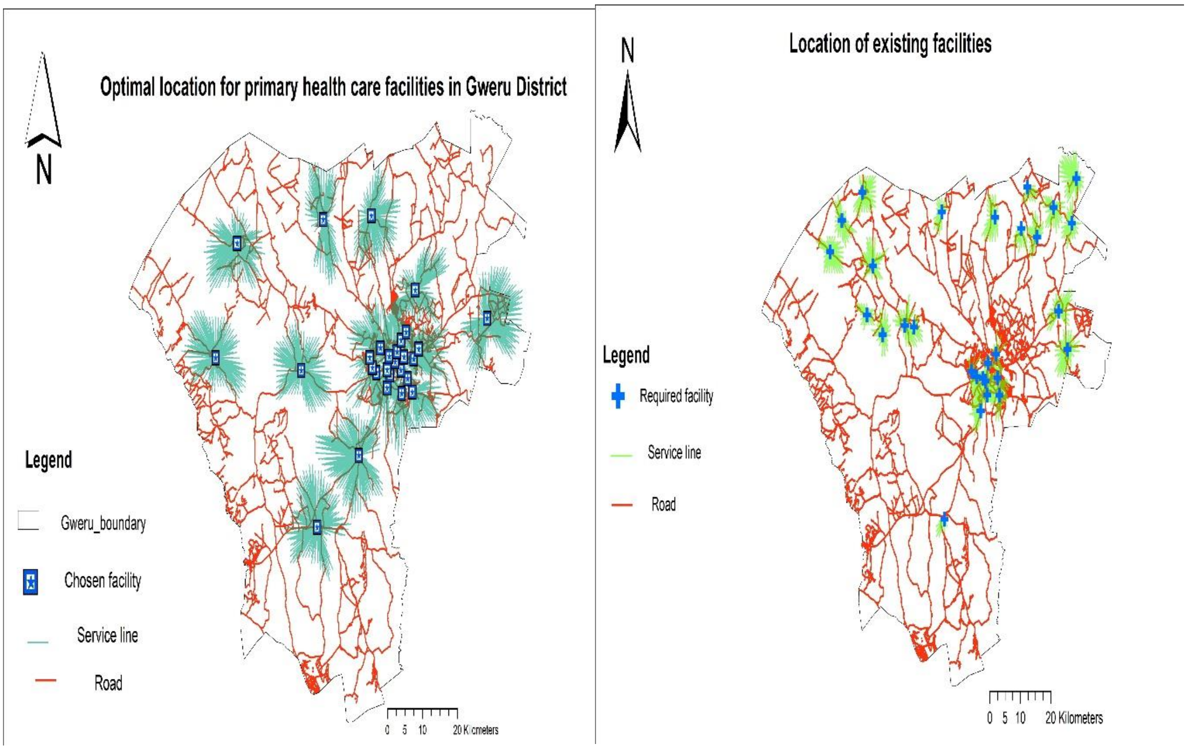
Name	FacilityType	DemandWeight	
Chiundura	Required	143	
Connemara	Required	754	
Gunde	Required	315	
Kabanga	Required	1136	
Lower Gweru	Required	487	
Maboleni	Required	689	
Madhikani	Required	1347	
Makepesi	Required	105	
Mangwande	Required	156	
Vungu	Required	543	
Whahwa	Required	614	
Masvori	Required	562	
Mlezu	Required	109	
Nkululeko	Required	516	
Ntabamhlope	Required	249	
Somabula	Required	137	
St Patricks	Required	242	
Dabuka	Required	1789	
Kariba	Required	7876	
Ivene	Required	3793	
Totonga	Required	39836	
Monomutapa	Required	20056	
Child Welfare	Required	31084	
Senga Poly	Required	8673	
Mkoba Poly	Required	18383	
Sino Zimbabwe	Required	902	
Nyama	Required	547	
Mkoba 1	Required	13062	

The results indicated that some of the facilities in Gweru urban like Totonga, Monomutapa, and Childwalfare and Mkoba poly are overburdened. These facilities serve more than the required population to provider ratio.

4.3 Comparing the theoretical locations with the existing locations

Comparing results of the model developed and the existing facilities show that there are in adequate facilities in the city. From the current situation there are 10 facilities in the city and in the model developed 7 additional facilities were located in Gweru urban to make sure that every individual access health facilities at maximum travel distance of 5km each facility with a capacity of 10 000 people. Comparing results of the two models carried out one for determining theoretical sites and the other for assessing the existing location of primary health facilities it is clearly shown that the existing facilities has lower accessibility than the theoretical locations. The existing locations covered 37% of the population while the theoretical locations cover up to 76%.It is also shown that there are more facilities located in Gweru rural on the existing locations while on the theoretical locations more facilities are located in Gweru urban. Facilities in Gweru urban serves a greater population than those in Gweru rural.

Fig: 18 comparison between theoretical locations and existing location of PHCs



Discussion

The optimal location of primary health facilities were determined using maximize capacitated model with finite capacity. From the location allocation model 28 facilities were located and demand of 10 000 was allocated to each. The study findings show that the determined optimal location achieved a coverage of 76% of the population within the required standards.32% of the population travels more than 5km from demand to facility. Population that reside in urban have better accessibility than those that reside in rural areas. Population in urban travel short distances as compared to rural. From the model developed most of the facilities allocated close to city center and most of the population in urban have good access to health care. The location allocation model locate facilities using the road network and there is poor road network in rural areas hence the population has poor access to health care.

Assessment of existing facilities was carried out and the results suggest that the current primary health care facilities are not optimally located to serve demand. The population served by the existing facilities within 5km is limited. Even after increasing the travel distance to 10km there are still some proportions of the population that have limited accessibility. 37% of the population is covered within 5km and population coverage is increased to 44% within 10km.This is because the method used to locate the existing facilities estimate distance using straight lines which is not appropriate since people travel through the existing road network. Moreover there are also some facilities that are overburdened and this might be due to rapid population growth in urban. To compare the existing facilities with optimal the spatial accessibility was calculated, areas with low accessibility has low coverage within the required standards.

CHAPTER FIVE

5 Conclusion recommendations and limitations

In this study the following objectives were addressed

To determine the theoretical optimal location of primary health facilities in Gweru District

To evaluate if the existing facilities are optimally located to serve demand

5.1Objective 1

The theoretical optimal location of primary health facilities were obtained using maximize capacitated model with finite capacity. The model successfully determine the optimal location of the PHCs.However the model did not allocate all the demand to the facilities under the recommended distance. Only 68% of the population was covered by the intended facilities. The other 32% of the population fall outside the service area which means the travel more than the recommended distance to attain health services. Doubling the recommended distance increase the population cover to 76%.

5.2 Objective 2

Assessment of existing facilities was carried out to see if the existing facilities are optimally located to serve the population. The results of this objective was not favourable. The optimality of existing facilities was examined by calculating the percentages of the population served by these facilities within the recommended distance and it was found that only 37% of the population has good access to the existing facilities. Increasing the travel distance to 10 km also increases the number of demand served. 44% of the demand is covered within a travel distance of 10km. Results indicated that there are some parts of the district that are outside the catchment area as defined by the recommended distance. It can be seen that most of the people residing in rural part of the district has low access to health care services. This could be due to poor road network in rural areas. People residing in the central part of the district (city) have high access to PHCs in the sense that residents in this area live in a poly-nucleated settlements and there are good road networks. However there other facilities like Mkoba, Totonga and Monomutapa are overburdened when demand is allocated to the nearest facility.

Finally results from the service area analysis were compared with the theoretical optimal locations.it was found that the total demand covered by the theoretical optimal locations is more than the demand covered by existing facilities. Also the number of facilities located in Gweru urban by the developed model exceeds the total facilities exist in the city.

In this study the optimal location of primary health facilities were generated by location allocation model. Comparing with the other studies of optimising primary health care facility locations, facility capacity constraint in terms of number of people per facility was taken into consideration and also make use of the existing infrastructure to estimate travel distance. However there are still some weaknesses in this study that need to be improved for future studies.

Results indicated that location allocation can be successfully used to determine optimal location of primary health care facilities. However it should be noted that the optimal locations determined may be located on unsuitable sites such as land occupied by other land uses. This case indicate the weakness of using fishnet on establishing candidate points. Future studies for determining optimal location for PHC should apply suitability analysis on establishing candidate sites. In this study the facilities that are outside the district but within the recommended distance threshold were not considered. To improve accessibility facilities that are outside the region but fall within the required distance should considered.

It is important for policy makers and planner to locate primary health care facilities on optimal sites that serve demand conveniently. GIS- based Location allocation model assist in making decisions on where to locate and also how to assign Also for existing facilities that are overpopulated their capacity should be increased such that they serve demand conveniently. It is also important for planners to utilize this method in assessing the existing facilities so as to see areas with shortages of health services and allocate health facilities to alleviate accessibility problems. Additionally it has been seen that there is low access to health care in rural areas due to poor road networks therefore it is essential for the government to construct good road roads in rural areas in order to achieve its goals of universality and equity in health services. In the past years there is rapid population increase in the city and the study clearly shows that there are some facilities in urban that are overburdened hence it is important for the government ant planners to increase the capacities of those facilities by adding more resources and health workers .Further more primary health facilities should be optimally located targeting current and future users.

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