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GIS Location-Allocation Model in Improving Accessibility to Health Care Facilities: A Case Study of Mt. Elgon Sub-County

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Abstract: ***The World Health Organization in its 58th World Health Assembly (WHO) called upon all nations to ensure that citizens should have "access to promotive, preventive, curative and rehabilitative health intervention at affordable costs". International standards recommend that healthcare facilities should be located within 5 km distance. However, such recommendations failed to take into consideration the terrain, the states of rural roads and means of transport. In Mt. Elgon Sub-county, close to 200 people lose their lives annually as a result of delay in getting proper health care services which is largely attributed to poor roads, rough terrain and inadequate means of transport. There is a need to increase geographic accessibility to these facilities. Specific aims of the study include: showing geographic distribution of health centers in Mt. Elgon District, examining accessibility to health care centers in the Sub-county, and to use GIS to propose optimum locations where future health centers ought to be constructed. It is well known that locating hospitals correctly is highly important in order to increase their accessibility. One method for identifying optimal locations in Euclidean space is a location-allocation model which minimizes the total travel time from supply locations (health centers) to the demand locations (human population). The types of data used include population data based on the 2009 national census, digital elevation model, and location of healthcare facilities, road network, disease statistics and Landsat image. From the findings, a total of 1 district hospital, a sub-district hospital and 10 health centers serve the entire Sub-County. Only 62.5% of the population can access the existing healthcare facilities within a distance of 5.0km. Construction of 6 health centers was found to help in improving accessibility to 90.0%. This ultimately can reduce the cost, pain and more so the number of deaths in the Sub-County linked to delays in accessing proper medical attention. The greatest limitation of the study rests on the idea that only health centers and District hospitals were used. Future studies should consider dispensaries and other private clinics in the analysis***.

Keywords: GIS, Location-allocation models, geographic accessibility, health centers, optimum location, unequal distribution.

1. Introduction

It has been argued that a healthier nation will support and spur economic growth and development. Globally, efforts have been directed by the relevant authorities to ensure that the local people are provided with proper and accessible health care services. This can be exemplified by the resolutions of the World Health Organization in its 58th World Health Assembly. At that time, 2005 WHO called upon all nations in the world to move towards having a national or universal coverage in terms of health services. With this all individuals should have "access to promotive, preventive, curative and rehabilitative health intervention at affordable costs" (Smart Global Health Kenya, 2013). To accomplish this, one approach is to ensure that healthcare centers and other important healthcare facilities are equally distributed and optimally located so that people can easily access them. Indeed the cost of accessing health care depends on numerous attributes among them distance that one travels to access health care services. In Kenya, there are still discrepancies in the distribution and accessibility of such services. Things are made worse due to lack of adequate and good road infrastructure, poor terrain and poor doctor to patient ratio (Mwangi, 2013). In Mt Elgon, the rough terrain, coupled with lack of proper means of transports makes it difficult for the residents to access proper health care services within the recommended time or distance. Recently, the first lady Margaret Kenyatta initiated a campaigned dubbed 'Beyond Zero' aimed at providing mobile clinics to help mothers deliver safely. However, this is still not enough and there is need to have a long term plan and solution. Scholars acknowledge that improving geographic accessibility to health care facilities is one of the steps towards meeting the global recommendation of WHO (Turin, 2010). To that effect, the present study purpose is to use GIS Location-allocation model to improve geographic accessibility to health care services in Mt Elgon Sub-county.

2. Literature Survey

Since the 1960s, location-allocation models have been applied to a wide variety of problem contexts, but with a general form of structuring service facilities to satisfy demands in optimal ways (Farahani & Hekmatfar, 2009). Location-allocation models can be used to determine the best locations for new facilities that provide services and commodities to users, and people in need of those supplies. In other words, the location- allocation model is the process that selects the optimal locations of facilities from a set of candidate locations and, simultaneously assigns demands to these locations in the most efficient manner, based on the distribution of demands (Lea, 1973).

The location-allocation models determine the optimal locations by using several measurements that are based on travel distance, travel time or other forms of cost functions. Researchers have developed a suite of techniques for carrying out location- allocation modeling. These techniques aim at finding the right sites for facility locations that can increase the accessibility and decrease the total weighted cost (e.g. Distance, traveling time, or other cost factors) (Noor, et al, 2009). For practical applications, researchers have used these techniques to find optimal locations for hospitals, fire stations, post offices, libraries, day centers, waste disposal sites, warehouses, schools, bank branches, and sites for monitoring endangered animals among others. Since selecting the optimal locations and allocating demands to them depend on both the demands and the supplies, location-allocation analysis must be determined simultaneously (Senzom, 2011). This means that the location-allocation models involve at the same time, the selection of a set of locations for facilities and the assignment of a set of demands to these facilities in order to locate and find the optimal locations. When the relationship between demands and supplies involves costs, or use of resources, the location-allocation models attempt to arrive at solutions that use the resources most effectively. The location-allocation models, each contains three primary components: 1) the demand locations; 2) the candidate locations for service facilities; and 3) a distance and/or time matrix holding distances or traveling time between service facilities and demand locations (Samat, Shatar & Manan, 2010).

Accessibility to public health facilities requires that the best locations for hospitals and other healthcare facilities are suitably located so that the population can quickly get services without travelling long distances which has been linked to loss of lives (Oppong, 1994). The choice of the best locations is one of the problems that face most local governments and national government in the world. Another problem that these governments face is determining how many facilities should be located within a certain area (Russell, 2008). The location - allocation method has been the only way that most city planners, researchers, policy makers and local governments apply in order to facilitate efficient location of facilities. The various location-allocation models used are: minimize the impedance problem, maximize coverage, minimize facilities, maximize attendance, maximize market share, and target market share.

There are numerous advantages of utilizing GIS location-allocation models. This technology offer engineers and municipal planners a better platform to critically view and choose the optimal location for public facilities (Oliveira & Bevan, 2006). According to Yeh & Chow, (1997), it also aids decision makers to make their selections successfully by examining different scenarios generated under different assumptions. All these are necessary prerequisite in resolving health service provision discrepancies in Kenya.

Despite the fact that various scholars have utilized the technology, there is no study to the best of the researcher's knowledge that considered population size, terrain, state of roads and land cover factors in proposing optimum locations for additional facilities. This study aims at filling that gap.

3. Methodology

Mt Elgon Sub-County is located in southeastern slopes of Mount Elgon, Bungoma County, and Western Province. It is characterized with evergreen dense to spare forest, mountainous vegetation towards the peaks and populated areas on the slopes. The region is also endowed with abundant wildlife, particularly elephants. The mean annual rainfall is between 1000mm-1800mm with daily temperature averaging between 15°C to 29 °C. Based on 2009 census, the population stood at approximately 300,000. The major economic activities include farming, livestock keeping, trade and tourism.

3.1 Data

The data set that was used in the study are summarized in table 1 and information included are names of data, source and year.

Table 1: Summery of data to be used

Data	*Source*	*Year*
Location of healthcare facilities (health care centers)	Ministry of Health/collect using GPS	2014
Population	Kenya National Bureau of Statistics	1999 & 2009
Road Networks	Survey of Kenya	2014
Administrative boundaries	Survey of Kenya	2014
Landsat Image (P170R059)	USGS Website	2014
Disease data	Ministry of Health	2013
Digital Elevation Model (30m)	RCMRD	2014

3.2 Data Processing

Maximize coverage model was deemed suitable for this analysis. The reason for its selections is because the model works well within the public sector in the location of emergency service facilities. It is a good model for locating facilities like fire stations which are always required to reach demand locations within specified time. Also, it can be used by the private sector in locating optimal areas for the establishment of retail stores to be accessed by large demands (Donnell, 2007).

Using population data, centroids were created for the 40 sub-locations which represented the demand points. This was followed by creating a database where all the layers (roads, population, and existing health care facilities) were saved. To create a new network geo-dataset, it was necessary that network analyst extension was checked. Then I right clicked on road shapefile and click on 'New ' to create 'Network dataset…'After doing all the above, the analysis phase starts. The researcher opened the Network analysts and proceeded to 'New Location Allocation'. A number of attributes are then populated from where facilities which in this case represents the existing health care facilities are loaded into the model. Then in the facility tab, I selected 'Required' and not 'Candidates' and accept the default.

The second attribute to be loaded were the demand points which in this case represents the population centroids. After loading the two, it was necessary to set some of the location-allocation properties; in the layer property window, under 'Analysis Settings' the 'Travel From' was checked to 'Demand to Facility' since people travel to healthcare facilities from their homes to seek medical attention. To choose the type of model or analysis that suits this case, in 'Advanced Setting' the 'Problem Type' was chosen as 'Maximize Coverage' because the idea is to maximize the population utilizing the existing health care facilities. Then, under 'Facilities To Choose' the existing number of health care facilities were selected (12), the 'Impedance Cut Off' refers to either time of travel or the minimum distance of travel, in this case it was set to 5km which is the standard travel time to a health care facility according to WHO. The problem was then solved to show the proportion of the population covered and those uncovered by the existing facilities.

To determine the best location, digital elevation model was used. Three major aspects that can be derived from DEM were of importance in determining the ideal location for construction of new healthcare facilities; these are slope, aspect and relief. Lastly, it was important to understand the land use and land cover of the study area. A 2014 Landsat image was processed using ENVI. Maximum likelihood classifier was used to generate the classes.

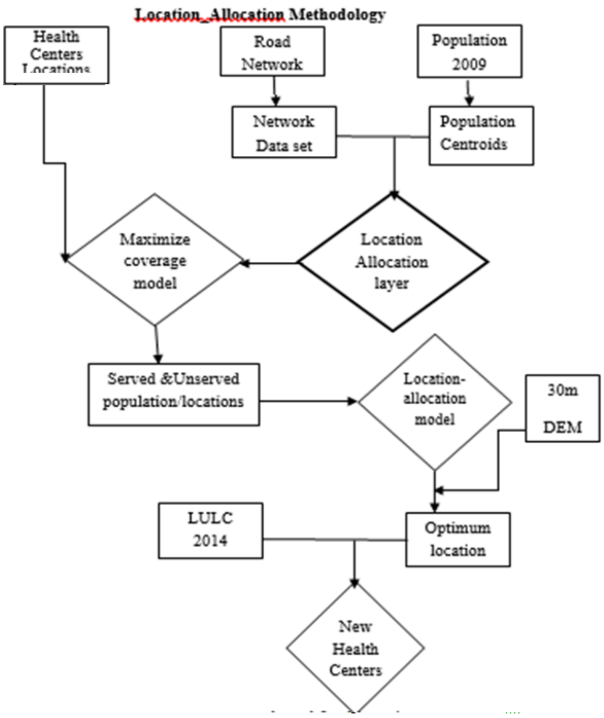

Figure 1: Conceptual Framework adopted

4. Results and Discussion

From the analysis, it is evident that the sub-country has a total of 12 health facilities, one being a district hospital, 1 a sub-district hospital and the rest health centers. It is worth noting that this study did not consider dispensaries due to the fact that they lack the capacity to handle complex health issues such as complicated pregnancies, chronic diseases, and serious injuries among others. This is attributed to the fact that there is a lack of adequate human resources as well as cutting edge tools and equipment. Senzom, (2011) also established the way in which health care facilities and qualification of human resources and equipment in health has a correlation with well-being of the affected population.

It is evident that more than half (8) of the existing health facilities are in Cheptais and Kopsiro Divisions. With regards to disease burden, Cheptais and Kaptama Division recorded higher numbers based on 2013 data.

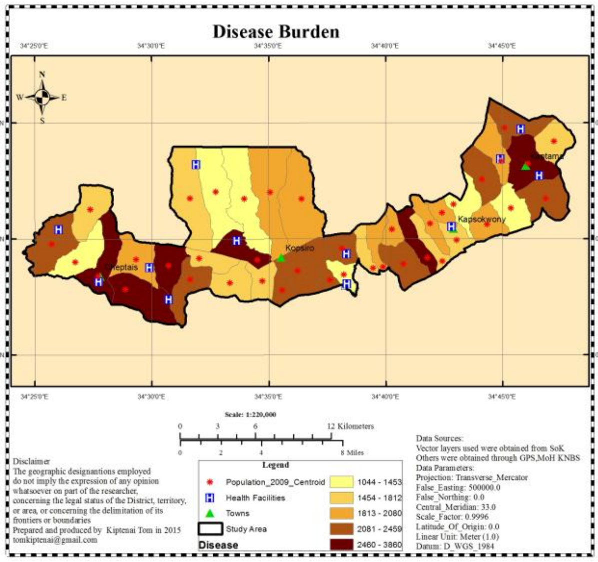

Figure 2: Distribution of Health Centers and Disease Burden

Based on the 2009 population census, Mt. Elgon Sub-county had a total of 293,421 where the lowest population based on sub-location was 2,819 while the highest was 15,710. In 1999, the population stood at 135, 201 where the least populated sub-location had 1,345 while the most populated sub-location had 7,345 people. From the statistics above, it is evident that there was a 53.9% increase in population over a 10 year period. This definitely has consequences in terms of stretching the available resources including health facilities. Close scrutiny of the map indicates that there was a rapid increase in population in Kaptama Division. This can be attributed to the conflicts perpetrated by the Sabaot Land Defense Forces, a militia group that forced residence from Kopsiro and Cheptais to seek refuge elsewhere.

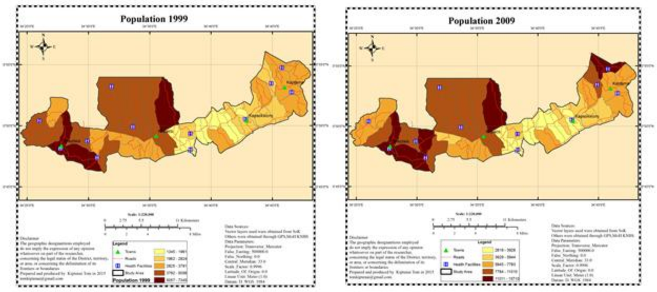

Figure 3: Population maps 1999 & 2009

After considering terrain, population size, land use and land cover, road network, and sunshine exposure, 6 optimum locations were arrived at. Ideally, only 62.5% of the population can access the 12 existing health Centers (facilities) within a distance of 5.0 km (25/40*100) Fig. 4. Considering that the sub-county had approximately 300,000 people, according to the 2009 national population census, only 185,000 people can access health services within the 5 km distance as recommended by the World Health Organization.

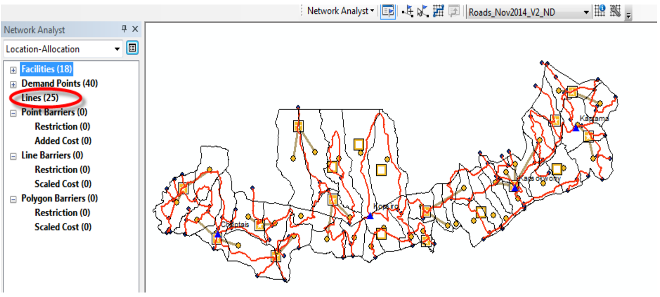

Figure 4: Served and unserved population

Construction of 6 health centers was found to help in improving accessibility to 90.0% (Fig. 5).

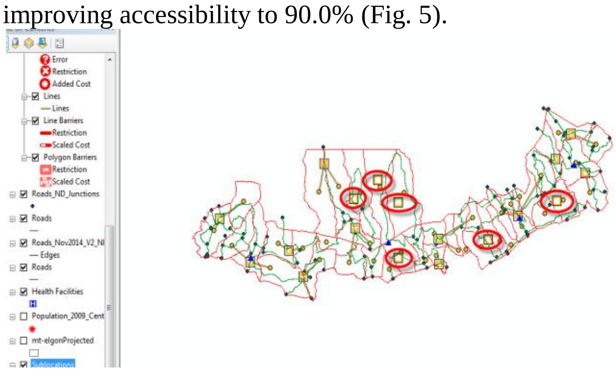

Figure 5: Showing optimal location for additional HCF

5. Conclusion

This study has shown that Geographic Information System and Remote Sensing technology can be used to critically evaluate the distribution and accessibility of healthcare facilities. Making it possible for experts to find out the current locations of health care centers and their coverage, to find out which parts of the study area (population) might be seriously uncovered (or under-served) within the World Health Organization standard distance of 5 km and to find out the best locations to construct new health centers with the aim of optimizing or improving geographic accessibility to health centers. The desire to maximize the total number of demands covered within the threshold of service distance or time by locating the candidate facility near the population density was achieved (Donnell, 2007). This is the desire of any government in providing its citizen with social amenities and services.

6. Future Scope

This study is associated with the following limitations;

- The study did not consider the contribution of smaller health care facilities eg. Clinics.
- There are cases where construction of good road network would solve the problem, this study did not dig deeper into this approach.
- Lastly, the researcher did not consider the effect of HC that are closer to Mt. Sub-county. This could potentially impact on the findings. Future studies need to consider such issues.

Future studies should include in the model health centers or hospitals that are within the 5km distance although they are outside the boundaries of the study area. Similarly, there is need to use the model with more variables and predicting future scenarios. This is key in helping government as well as the private sector in proper planning.

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Author Profile

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Tom K. Kiptenai graduated with Bsc Wildlife Management from Moi University in 2009. He later worked with the Kenya Wildlife Service for 1 year. While pursuing his master degree at Jomo Kenyatta University of Agriculture & Technology, Tom worked with Regional Center for Mapping of Resources for Development as a Remote Sensing Consultant for 2 year. He currently works with African Wildlife Foundation as Geographic Information System Assistant.