Application of Geographic Information Systems (Gis) in the Selection of Suitable sites for health facilities establishment

Article by Ifezue Uchechi Grace
Phd Public Health, Texila American University , Nigeria
Email: grifezue@yahoo.com

Abstract

OBJECTIVE: To prepare a report on the application of Geographic Information Systems for the selection of suitable sites/locations for health facilities establishment.

METHOD: Information provided, concerning the application of Geographic information systems in the field of Health care.

CONCLUSION: The potentials and capabilities of Geographic information systems in planning and decision making is widely known as an experimental tool but its real world application is yet to be realised. Geographic information systems can be used effectively as tool for decision making in relation to optimum gainful utilization of available medical resource in various areas.

KEY WORDS: Geographic Information Systems, Health Facilities.

Introduction

The establishment of health facilities in an area is one of the planning fields that use spatial data in its resource allocation process. Health authorities and health officers have been required to keep registers and carry out analysis of costs, benefits and health needs (Hirschfield *et al*, 1995). Today, Geographic information systems (GIS) provide useful techniques regarding the capture, maintenance and analysis of spatial data. The issue of location (site) for any activity is a recurrent one in spatial behavior. The objective of selecting a suitable site for any project is to maximize profit as well as to take care of the health needs of inhabitants in a community, reduce capital required for site development and promote suitable development as noted by Pindiga,(2001). The choice of the best site for a health facility will be based on well-defined criteria that will support cost effective, environmentally effective and easy access to hospitals.

Geographic information system (GIS) is a computer based tool for mapping and analyzing things which have location, as opined by Kosoko, (2003). Information stored in a GIS data base can be viewed together as many different layers and are needed depending on user requirements. This ability distinguishes Geographic information systems from other information systems and makes it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes and planning strategies (Pindiga, 2001). Health care refers to the treatment and management of illness and the preservation of health through services offered by the medical, dental, pharmaceutical, clinical laboratory science (in vitro diagnostics), nursing and allied health professions. Health care embraces all the goods and services designed to promote health including preventive, curative and palliative interventions, whether directed to individuals or to populations (World health organization, 2000).Health facilities are places that provide health care, they include hospitals, clinics, outpatient care centers, and specialized care centers such as birthing centers and psychiatric care centers. (Wikipedia 2015).

Concept of geographic information systems

A geographic information system (GIS), is a computer based tool that organizes and displays data. However a lot of definitions have been made on this concept in so many literatures written by several authors; Sowton, (1991), defined Geographic information

systems as a system that allows the capture, updating and display of a number of previously unconnected data sets, bringing them into a common reference system for spatial analysis from which relationships can be identified and decisions made. Also, Kufoniyi (1998), defined Geographic information systems (GIS), as computerized tools for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth.

Decision makers in health and social service agencies work by providing a definition of geographic information system (GIS) as an enterprise GIS and the benefits of issues of GIS in the health and social services areas, also they provide a description of the planning process needed to establish enterprise GIS in a given organization. Environmental System Research Institute,(1999), also explained Geographic information systems as a computer based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common data base operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps.

Site suitability analysis is one of the very important application of Geographic information systems of which Davis, (1996) stated that it is a means of sifting through data files to select site that best satisfied some set out conditions. In considering a suitable site for a health facility, the site would be selected by identifying areas which either support or prevent the development of the planned health facility for example noise from airport and market while factors that support the establishment include proximity to primary road, access to trunk line, relative gentle terrain etc.

One of the methods of solving the site selection problem was the use of the location allocation models. According to Transer *et al*, (2001), location involves three basic elements.
1. A set of consumers distributed spatially over an area.
2. A set of facilities to serve them.
3. A network data connecting demand point to service points.

To solve a site selection problem therefore involve setting some criteria and choosing the site that best satisfies the set down condition or criteria. In a related study by the Ministry of municipal and rural affairs, Saudi Arabia (1980), the planning committee set a criteria for the establishment of public hospitals such that each hospital has a catchment area of 4 Kilometers and serves a population of 60,000 people. The area of the city of Riyadh that has the highest concentration of private hospitals was the central area with a population of over 600,000 and serviced by a hospital. The proliferation of private hospitals within this zone was brought by the inadequacy in location of public hospitals.

Perry & Gesler, (2006) gave the view that proximity to primary health care has long been considered a major factor contributing to the health of the populations. Also Joseph & Philips (1984), identified population distribution as being vital for health resource allocation; although such decisions are taken long before date that allows resource allocation to be assessed. The apparent consideration for health facility site selection condition had led to poor patronage and under-utilization of the established facility. Physical accessibility of health services is determined by geographic location of clients' home stead in relation to available facilities (Transer *et al*, 2001).Obafemi (2003), on writing on sustainable use of urban land recommended that while health center and dispensaries may be sited on area of less than 0.5 hectares, General hospital required about 1 square kilometer or more and on a land with gentle slope of up to 6 degrees (60). This is to reduce high construction and reduce risk of erosion.

Pindiga (2001), identified the following criteria for establishment of Health facilities:
1. Site must be on a terrain with elevation not greater than 625 meters.
2. Area should not be less than 4 Hectares.
3. Site must be on a slope of not less than 20 degrees (200).
4. Site must not be far from existing water mains.
5. Site must be accessible within 5 kilometers of a major road.

6. Site must at least be 300 meters from any industrial, commercial and high density population areas.
7. Site must not be more than 4 kilometers from another existing hospital and not more than 5 kilometers from town center.

It has to be noted here, according to Pindiga (2001), that the conditions and constraints for the site selection is a function of:

1. The application at hand.
2. The study area.
3. The facilities existing within the study area as well as the available data set and the result of the user requirement survey.
4. The hard ware and software available for the exercise.

A better, more dynamic and more universal approach to site selection problems was found in Kosoko (2003), this method aims at solving the immediate and future problems of site selection within an application area. It involve the use of buffering and overlay by intersect operation and spatial search (database query) to solve any site selection problem within an area.

Healthcare planning and geographic information systems.

According to Abdul (2001), one of the basic objectives of healthcare planning in any part of the world is to have equal access to health care for all, irrespective of ability to pay. This means that every residence should have equal chance to go to clinics and hospitals. To meet this objective and other ones, health authorities are required to make careful analysis about the real demand and supply of health care facilities at their areas. These analyses and studies can be grouped into three areas which are:

1. Spatial changes in health status.
2. Spatial Epidemiology.
3. Health care facilities accessibility and utilization.

Each of these topics has a spatial dimension which means that Geographic information systems can be used for their studies.

1. Spatial changes in health status.

One of the facts about health status in a micro or macro scale is that it changes across the space. Health authorities always investigate and analyze the health status at their areas and make sure that health needs are satisfied. Abdul (2001), was of the opinion that locality definition is considered an important issue for health care facilities planning studies. The idea here is to determine the socio-economic classification for the area surrounding certain health facilities and then relating the local profiles of such area with the health care needs. Once the socio-economic status of any location is defined, then Geographic Information Systems can be used to map and tabulate the distribution of such status. A good example of using GIS for linking social profiles with health needs is found by Hirschfield *et al*, (1995), which have produced patient profiles for every health facility catchment area. Such studies usually involve matching point-referenced, post coded socio-economic data, particularly deprivation indications (Gatrell & Senior, 1999). For example, health status can be viewed through comparing the actual number of mortalities in an area with the actual number of and sex variations in the area concerned (Birkin *et al*, 1996). Here Geographic information systems can be used successfully for describing spatial variation of mortality at parts of any country. Once the mortality rate of each region is entered into the GIS, then the mapping and analysis tools of GIS can be applied to present out the regions that have high rates of mortality. The regions with high rates require more attention from health authorities in order to improve their existing health status. In addition to mortality there is much other health indicators that are used by health authorities, such as fertility rates, which help them to access and monitor the required health services.

2. Spatial epidemiology

The second area of health care research is known as spatial epidemiology. There are several questions that are commonly asked in spatial epidemiology. Studies which include;

- Where are the incidences located?
- What are the environmental characteristics of this area?
- Are there associations between health incidences and the environment at other locations?
- What patterns are evolving?

GIS is considered as a useful tool for answering the preceding questions. For example, GIS can define the actual location of health events, and then overlay analysis can be used to create new spatial relationships and to tag the various socio-economic and environmental information to the health data. (Nicol, 1991).

Advances in geographical information and mapping technologies have created new opportunities for public health administrators to enhance planning, analysis, monitoring and management of health systems. Health mapping has evolved from Dr. John Snow's cholera death mapping in the mid ninetieth century to the latest computer based mapping systems. In 1854, according to Colledge *et al*, (1996), Dr. John snow depicted a cholera outbreak in London using points to represent the locations of some individual cases, possibly the earliest use of the geographic method. His pump (The Broad Street pump) whose handle he disconnected, thus terminating the cholera outbreak within the heart of the cholera outbreak.

Map made by John Snow in 1854. Cholera cases are highlighted in black.

Source: Wikimedia.org (2015).

There are several studies that have applied Geographic information systems for these issues. For instance Brown *et al* (1991), have used Geographic information systems for the mapping of spatial variations in health care provision in Mersey side. Wirgley (1991), have also used GIS in mapping incidence of diseases in relation to population types. Another example of Geographic information systems application in epidemiology is called the Health and Environment Geographic information systems (HEGIS) which is being established in Europe by the World Health Organization (Nicol, 1991). It involves the creation of European wide environment data set, and the aim is to research relationship between health and the environment to aid policies and management. Most of the spatial epidemiology studies must be based upon accurate knowledge of the population. Therefore access to details of population composition and socio-economic characteristics are very necessary for these studies. Spatial epidemiology studies are concerned with finding good description of spatial incidence of disease as well as the modeling of such incidence. One way of describing the spatial distribution of a certain disease is by visualizing the GIS choropeth maps that show the spatial distribution of such disease. In such maps, disease rates are plotted over the base map to define the areas that are highly affected from the related disease. Further analysis and modeling of the spatial incidence can be carried out using density estimation technique that is used to predict the spatial variation in diseases risk. (Gatrell & Senior, 1991).

3. Health care facilities accessibility and utilization.

According to Gatrell and Senior, (1991), this area of health care research concerns with all the issues that are related to the location of health care facilities. These issues include the optimal location of hospitals and clinics, the relationship between existing locations and health care needs and the assessment of facility accessibility. The planning of any health care system should have answers to the following important questions.

- What are the population needs for health care and how should resources be allocated to the population they are designed to serve?

Gatrell & senior (1991), also suggested that Geographic information systems can assist in finding comprehensive answers for the preceding questions.

For example, Johns and Bethham (1995), have used GIS to test for a relationship between health outcomes and accessibility. Forbers & Todd (1995), have also used GIS to evaluate the potential locations for a new radio therapy unit for cancer treatment in North West England.

Finding the best location for a health care facility is considered as one of the health authority task in order to optimize resources. The best location for a facility can be identified using for example location allocation models that are now been integrated to the GIS softwares such as Arcinfo version 7.

Evaluating the accessibility of existing health facilities is also another task carried by health authorities. Here, the health planners determine the causes, which have poor accessibility for certain, health facility and then prepare proposals for improving such low level of health care accessibility. One way of improving such accessibility is by increasing the capacity of the related health facility, but this can only be achieved after intensive analysis of the area that contain such a facility (Abdul, 2001).

Health care planning data.

Balraqui (1997), suggested that in order to evaluate the existing location of a health service or to prepare a new site location for a health facility, health care planners have to collect large set of data that there can be used for relevant health care issue. There are several ways of classifying this type of data, but one method is based on the GIS data format types, that is, dividing the health data into three major groups which are point, area and line data. In a GIS, point data can be a model for locations of residences, hospitals or ambulance stations. Each of the point data can have different attribute information. For example the locations of individuals might include attributes for the presence or absence of a disease, age, gender, occupation and so on. Population zones or census data on the other hand are examples of area data format which can be captured and stored in GIS and can be used for different health care studies. For instance census data can be used to analyze the socio-economic status of certain patient locations. Finally, the line data such as road network are used in GIS to study the travel journey to and from health facilities locations. They are also used by emergency vehicles and to identify how fast ambulance vehicles reaches to patient locations. (Balraqui 1997).

Using geographic information system in health facilities planning.

According to Abdul (2001), one area of Geographic information system research in health care planning field is concerned with measuring accessibility to health facilities. This part will concentrate more on this issue and explain how GIS is used to analyze accessibility to hospitals in an area. There are three important factors that affect the level of accessibility in any facility location. These are:
- The capacity of the facility.
- The amount of demand for such facility.
- The transportation network that communicate such demand to the relevant capacity.

The database

Abdul (2001), also noted that in order to build this application, the study will have to collect large set of data that are then entered into the GIS to form the database of the application. This means that all of the collected data will be in paper format that is, they were not digital. Accordingly, all of the collected data will be entered into GIS using the *digitizing* method. The study will capture maps (GIS coverage's) and then add to them their relevant attribute (non-spatial data). This coverage's are the road network, the hospital locations and the population coverage. The non-spatial data which are hospital size (capacity), number of people who live in each district of the city and the population density of these district. All of these are then used for the modelling process of hospital accessibility.

The modeling process

Once the required data have been captured into GIS, then the following step will be to decide about the relevant analysis methods that may be used for determining hospital accessibility. There are three main GIS spatial analysis function that could be used for analyzing the accessibility and selection of suitable sites for any selected facility location. The first one is known as the buffer analysis which draw buffer around existing proportion to the latter size and capacity (Davis 1996). The second method is related to the GIS network analysis module where population in a network is allocated to the nearest facility locations. Site suitability or site selection analysis is the third GIS function that identifies sites according to the suitability for the location of a health facility under a set of certain factors. Looking at these three GIS functions, the study will select the third GIS function that is, site suitability analysis module as the analysis tool for determining health facility establishment in a particular location. His analysis according to Abdul (2001), will use the service area model that in one of Arcview (a GIS Software produced by Environmental Systems Research Institute, ESRI, USA) for evaluating the selection of suitable site for establishing a health facility. This function can find the accessible streets within certain distances of a site and accordingly the streets which are not selected by this function are representing the problem areas. (ESRI, 1997).

Flow chart of procedure
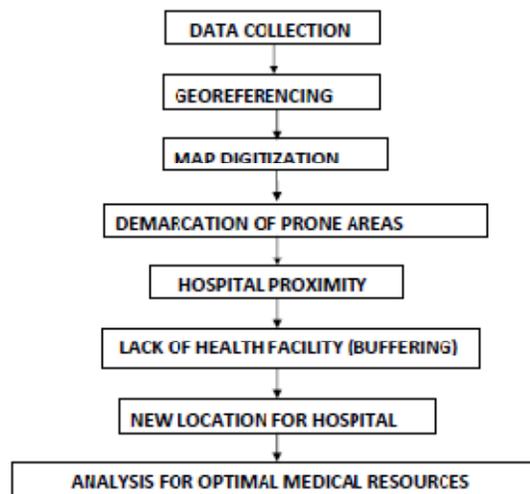
(Sumi Singh 2006).

Conclusion

Identifying health care need is one of the important tasks which health authorities frequently do. Health planners keep analyzing the changes that occur on health care demand. These changes usually require quick response from health authorities in order to keep matching health care facilities supply with the relevant demand. This is a large task that needs huge set of data including health facilities location, catchment areas, population statistics etc. Geographic Information Systems in particular can help the health authorities to make their required jobs in an efficient manner. For examining health facility distribution, identifying deprived areas as well recognizing areas for future investments. It can be said that GIS is a better tool for handling spatial and descriptive data. Furthermore GIS functionalities are ideal for evaluation within given constraints. Multisource data can be analyzed together with appropriate derivation of new parameters.

References

[1.] Abdul, K.A.M. (2001).*Application of GIS in Health Care Facilities Planning*. Jedda: Saudi Arabia.

[2.] Balraqui, N. (1997).*Demographic Changes in Jeddah*. Jeddah: Unpublished Phd. Thesis.

[3.] Birkin, M., Clarke, G., Clarke, M. & Wilson, A. (1996). *Intelligent GIS*. Cambridge: Geo-Information Int.

[4.] Brown, P., Hirschfield, A. & Batey (1991). Applications of Geodermographic Methods in the Analysis of Health Condition Incidence Data. *Papers in Regional Science*. 70 (1), 329-344.

[5.] Davis, B. (1996).*Geographic Information Systems, A Visual Approach*. USA: Onward Press Camiro.

[6.] Environment Systems Research Institute (1997). *Getting To Know Arcview*. Cambrige: Geoinformation Int.

[7.] Environmental Systems Research Institute (1999). Enterprise GIS In Health and Social Agencies. *An ESRI White Paper*. 1 (1), 5-8.

[8.] Forbers, H. & Todd, P. (1995). *Review of Cancer Services*. Liverpool: University Of Liverpool.

[9.] Gatrell, A. & Senior, M. (1991). *Health and Health Care Application in Information System Principles and Application*. United Kingdom: John Willy & Sons.

[10.] Gilbert, E.W. (1958). *John Snow's Cholera Map*. United Kingdom: York University.

[11.] Hirschfield, A., Brown, P. & Bundred, P. (1995).The Spatial Analysis of Community Health Services. *Journal of International Research Society*. 46 (1), 147-159.

[12.] Johnes, A. & Bentham, G. (1995). Emergency Medical Service Accessibility and Come from Road Traffic Accidents. *Public Health*. 109(2), 169-177.

[13.] Kosoko, S.O.A. (2003). *Site Selection through Design User Interface*. Federal School Of Surveying, Oyo.

[14.] Kufoniyi, O. (1998). Database Design and Creation on Ezigbo. *C.U. (Ed)*. (3), 52-55.

[15.] Nicol, J.(1991). Geographic Information System within the Healths, the Scope for Implementations. *Planning Outlook*. 34(1), 37-42.

[16.] Obafemi, O. (2003). *Land Subdivision Basics*. Ibadan: Pent House Publications.

[17.] Perry, M.& Gesler, A. (2006). Analyzing Theme, Space and Time. *ACM International Symposium on Geographic Information Systems*. 147-154.

[18.] Pindiga, A.M. (2001). *Application of GIS in Site Selection for an additional Public Hospital in Bauchi Metropolis*. Federal School of Surveying Oyo. Unpublished PGD. GIS Project.

[19.] Sowton, S. (1991). Development of GIS related activities at the ordinance survey. *A paper presented at the survey coordination and advisory board on Survey Training and conference*: Markudi, Benue State.

[20.] Sumi, S. (2006).*GIS Application in Health Care Facility*. Kirkee Cantt: Bhosle Nagar.

[21.] Transer, F., Hosegood, V., Benze, J. & Solarch, G. (2001). New Approaches to Spatially Analze Primary Health Care Usage in Rural South Africa. *Tropical Medicine and Informational Health Journal*. 6 (1) 2-5.

[22.] Wigley, N. (1991). Market-Based Systems of Health Care Provision. *The NHS Bill and Geographical Information System, Environment and Planning*. (23), 5-8.

[23.] Wikipedia, the Free Encyclopedia. (2015). www.wikipedia.com. Retrieved at 4.00pm on 10/08/2015.

[24.] World Bank. (1993).*World development report*. New York: Oxford University Press.

[25.] World Health Organization Report (2000). *Why do Health Systems Matter?* WHO.