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A GIS-Based Multi-Criteria Assessment of Health Facilities Distribution in Bukuru Town, Plateau State, Nigeria

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MCDA has been integrated with GIS for effective decision making with wide application including participatory design to develop (public) health decision support systems, making good decision in healthcare, environmental health among several others. Hence, this research applied multi criteria analysis in assessing the distribution of health facilities in Bukuru town. The study adopted Open Data Kit (ODK) app in obtaining information, questionnaire administration, and health facilities inventory from the Plateau State Ministry of Health and Field Survey. Analytical Hierarchy Process (AHP) was used in the health location analysis and the criteria levels of importance were weighted using Saaty's scale. Data on the location of health facilities were imported into ArcGIS for analysis while data from questionnaires were analysed using Microsoft Excel and JASP. The analysis culminated in the generation of a Criterion map. The study revealed 19 health facilities in Bukuru town comprising of four Secondary and 15 Primary Health Centres. 33.6% of the total population of Bukuru town are underserved by health facilities in the study area. Some of the challenges facing the distribution of health facilities in the study area include low patronage, poor access road, and location of the facility. The study concluded that more health care facilities especially SHC should be provided. The AHP preference matrix proposes improvement on the type of health facility in the study area based on access to the facility. Furthermore, this infers that additional health centres should be introduced to cover for the shortage in areas that lack health facilities in other to ensure even distribution of health facilities.

Keywords: Analytic Hierarchy Process, GIS, Health Facility, Location, Weight

Introduction

Cities in the world are growing as a result of population growth and continuous migration of people from rural to urban areas (Saleh, Ahmad & Biswajeet, 2013). It is envisaged that before 2050 the world's population would be 9.7 billion (U N Department of Economic and Social Affairs, 2015) as a result of rapid urbanization experienced by these cities. The rapid urbanization experienced in these cities often generate a lot of problems which range from poor transport systems, poor health facilities and the lop-sidedness of public facilities and infrastructures in the country of which their inadequacies manifests in the prevailing socio-economic problems in most developing countries. These problems are more pronounced in developing countries where less regard is given to urban planning which is evident in the uncontrolled and unguided sprawl of towns and cities without commensurate provision of the community facilities and infrastructure services (Wapwera *et al.*, 2015).

In other words, these phenomena are also peculiar to Bukuru, Plateau state. Facilities in Bukuru are inadequate and below planning standards. Lack of maintenance, over use and poor distribution of these facilities have led to various problems ranging from poor water supply and sanitation, poor electrical infrastructure, inadequate waste disposal techniques, poor schools, inadequate traffic systems and poor distribution of health care facilities. In addressing these problems, authors and scholars have highlighted means

to enumerate the challenges of lop-sidedness in facility distribution. McGrail and Humphreys (2014); Tao *et al.* (2014); Blumenthal and McGinnis (2015); Neutens (2015) researches developed and evaluated a model through which accessibility to health care facilities could be assessed with appealing results.

However, utilization of these facilities has failed far below the invested resources and output potentials of these investments. Which is why Multicriteria Decision Analysis (MCDA) was introduced by Jacek Malczewski (1999). MCDA, is a valuable tool that we can apply to many complex decisions. It is defined as a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making (both in daily life and in settings such as business, land use planning, government and medicine). Multi Criteria Decision Analysis (MCDA) approach provides a guide through which policy makers and other stake holders can effectively site health care facilities with high level of accessibility based on needs while considering the current economic uncertainties and continuous increase in population. Accessibility related problems and spatial decision, are large sets of feasible alternatives, multiple conflicting and incommensurable evaluating criteria are always involved. MCDA is useful for: Dividing the decision into smaller, more understandable parts, analysing each part and integrating the parts to produce a meaningful solution.

Geographic Information Systems (GIS) - a database system with specific capabilities for spatially referenced data as well as a set of operations for working with the data has been integrated with MCDA for effective decision making with wide application in: modelling the location of new services (Feizizadeh *et al.*, 2014; Malczewski & Liu, 2014; Singh *et al.*, 2017); participatory design to develop (public) health decision support systems; (Malczewski & Liu, 2014), detecting flood susceptible areas; (Malczewski & Rinner, 2015), making good decision in healthcare; (Hunink *et al.*, 2014), environmental health among several others. Hence, this research tries to effectively apply multi criteria analysis in assessing the distribution of health facilities in Bukuru town.

Aim and Objectives of the Study

This paper is aimed at evaluating distribution of health care facilities in Bukuru town using MCDA techniques to discern areas that lack adequate health care facilities with the following objectives;

i. To identify existing health facilities.
ii. To determine the existing service radius of health facilities.
iii. To identify factors influencing distribution of health facilities.
iv. To use MCDA techniques to solve challenges facing distribution of health facilities in Bukuru town.

This study does not include areas or issues regarding health of individuals or distribution of materials needed in the health sector nor does it consist of pharmacist, chemist, and non-formal health services such as traditional healers.

Conceptual Framework

Global Health Facility Policy Development

In other to improve global capabilities in planning for health facilities, the World Health Organization (WHO, 1992) developed guidelines entitled "District hospitals: guidelines for development" because they recognized that the 21st century will bring new challenges regarding the allocation of health facilities worldwide. These guidelines are intended to be used by planners, engineers, architects, aid agencies, managers and leaders at district levels based on the needs of the population.

Above all, the construction of a new health facility, or changes in an existing one, should be carefully correlated with the needs of the people, by using a health service development plan which establishes the strategy for achieving the objectives of the health services (WHO 1992).

A survey of the Member States of the Western Pacific Region by the WHO (1992) revealed that primary health care facilities serve communities of 5,000-10,000 people, and hospitals serve communities of 50,000-500,000. In some countries, an intermediate

level of primary health care facility exists, serving populations of 10,000-50,000.

Health Facility Policy Development in Nigeria

In Nigeria, a cardinal objective of the Federal Government of Nigeria was to provide health care facilities as a sick labor force cannot improve the economy of the country no matter how skilled (Scott-Emuakpor, 2010).

Health facilities in Nigeria have been characterized by short term planning using the various National Development plans as is the case with planning of all aspects of life in Nigeria (Ijeoma *et al*., 2016). Although the development plans appeared to have focused attention on trying to improve the numerical strength of existing facilities rather than evolving a clear health care policy.

Health Facilities Standard in Nigeria

There are three fundamental levels of health care facilities in Nigeria: Primary Health Care (PHC), Secondary Health Care (SHC) and Tertiary Health Care (SHC). The PHC serves as fundamental basic health care and includes dispensary, clinics, neighbourhood health centre and maternity homes. While SHC facilities provide specialized services (dermatologists, cardiologists) and include community health centres and hospitals which provide emergency services, neonatal care, comprehensive emergency obstetric, gynaecologic services, general medicine, general surgery. And lastly THC facilities offers specialized consultative healthcare usually on referral from primary and secondary healthcare for advanced medical investigation and treatment. Examples include regional hospitals, specialist hospitals and university teaching hospitals.

Multi Criteria Decision Analysis (MCDA)

According to the Natural Resources Leadership Institute (2009), Multi-Criteria Decision Analysis, or MCDA, is a valuable tool that we can apply to many complex planning decisions and is most applicable to solving problems that are characterized as a choice among alternatives. MCDA has all the characteristics of a useful decision support tool which helps us focus on what is important, logical, consistent, and easy to use. It is a step by step process concerned with shaping and solving decision and planning problems involving multiple criteria.

In MCDA, various techniques could be applied in health facility distribution including; Analytical Hierarchy Process (AHP), Weighted Sum Method (WSM), Elimination and Choice Translating Reality (ELECTRE) etc. However, the AHP method was used in this study because it offers a systematic approach for prioritizing alternatives when multiple criteria must be considered in decision making.

Table 1: Planning standards for the location of PHC, SHC and THC facilities.

Health Facility	Category	Population Served	Range (km)	Area (Hectares)	Level
Dispensary	PHC	0 – 50	1	0.05	Neighbourhood
Maternity home	PHC	300 – 500	2	0.1	Community
Neighbourhood health centre	PHC	0 – 300	2	0.5	Neighbourhood
Clinic	PHC	300 – 500	1	0.1	Neighbourhood
Primary health centre	PHC	500 – 1,000	2	2.5	Neighbourhood
Community health centre	SHC	10,000 – 15,000	3	10.0	Community
Hospital	SHC	20,000 – 50,000	3 - 4	20.0	District
Specialist hospital	THC	150,000 – 200,000,000	50 - 100	30.0	Region

Source: WHO (1992)

Furthermore, this method enhances decision making and analysis by assigning weight to certain related factors, while combining multiple criteria influencing the existence of certain procedures, and it typically leads to ranking of alternatives. MCDA combined with GIS offers a set of methods that can provide transparent and systematic decision support for an integrated research on public health. Hence, a decision support model can be developed to guide policy makers in meeting societal demand of its citizen while minimizing cost (Yakubu *et al*., 2017).
In the last few years there has been a tendency to use participatory techniques like MCDA combined with GIS in various research works.

Materials and Methods

Data Collection

The data required for this research was obtained primarily from designed questionnaires administered to health facilities using the ODK (Open Data Kit) app. The sampling frame was the list of the health facilities got from the Plateau State Ministry of Health and Field Survey. A total number of 19 copies of questionnaires were used for this research for the 19 health facilities identified in the study area. Each of the questionnaires contain the criteria (target population, service radius, type of health care facility and accessibility) which were used to make decisions using the Analytical Hierarchy Process (AHP) and then categorized to show the level of importance of the spatial distribution factors affecting health facility location. The criteria were then weighted according to their level of importance using Saaty's scale.

The secondary data was gotten from already published documents like government bulletins, past theses, internet sources, textbooks, journals and Google earth.

Selecting the Criteria or Factors Influencing Public Health in the Study Area

To select the criteria or aspects influencing health facility location in the study area, the factors considered included the population, service radius, type of health care facility and accessibility. These factors were selected due to the critical role they play in determining distribution of health facilities.

Weight Assignment

The weight of each factor identified as criteria was determined using AHP developed by (Saaty, 1980). The scores were based on the relative weight of pair-wise comparison rated between scales of 1-9 in Saaty scale of weight assignment (Table 2) in order of relative importance. Pair-wise comparison matrices of the assigned weights of the map themes along with the individual features were then normalized to obtain the Eigen vector which was then run through a Matlab program to obtain the overall preference matrix. The pair-wise comparison represents relative importance of the factors under study.

Furthermore, the consistency index (CI) defined as the measure of consistency was determined using the equation (i) (Saaty, 1980).

$$CI = \lambda max - n / n - 1 \quad \text{.....(i)}$$

Where n=number of factor, λmax = consistency or Eigen value.
The consistency ratio (CR) was determined using the relation:

$$CR = CI / RI \quad \text{.....(ii)}$$

Where CI is the consistency index, RI is the random consistency index defined by a value 0.58 for n=3 (Saaty, 1980).

Table 2: Saaty scale of weight assignment to parameter under study.

Less importance			Equally important		More important			
Extremely	Very strongly	Strongly moderately	Equal importance		Moderate strongly		Very strong	Extremely
1/9	1/7	1/5	1/3	1	3	5	7	9

Source: Saaty (1980)

Method of Data Analysis

Data on the location of health facilities were imported into ArcGIS by arranging the geographical coordinates on Microsoft Excel. The file was saved as comma delimited to create dot maps showing the health facilities, the wards in the study area, type of health facility and service radius of the facilities. Data from questionnaires were analysed using Microsoft Excel and JASP to get descriptive statistical outputs such as tables, charts and maps for comparative analysis of the important variables to show the factors affecting the distribution of health facilities in the study area.

After selecting criteria and assigning weights to each factor according to their level of importance, the generated information was prepared and represented in the form of a Criterion map which models the preferences of the decision maker concerning a particular concept (Chakhar and Mousseau 2015).

Results

In identifying the health facilities, it was revealed that there are 19 health facilities in Bukuru town as seen in Table 3.

It was observed that Bukuru town has only four (4) SHC and fifteen (15) PHC. Therefore, the four SHC facilities in the area serve only 60,000 people while the fifteen PHC facilities serves 15,000 people maximally.

Table 4 infers that only 75,000 people out of the total population of Bukuru town (112,982) can be served by the existing facilities. It implies that 37,982 people are underserved by health facilities in the study area. Therefore, more health care facilities should be provided.

Existing Service Radius of Health Facilities

In examining the service radius of the health facilities, it was ascertained according to Shankland Cox (1980) in his general report on the Greater Jos Master Plan of 1973 that the maximum distance to health facility is 500m. Therefore, 500m buffer was applied to each facility using ArcGIS and the outcome is shown in Figure 2.

Table 3: Name and coordinates of health facilities

S/N	Name of Health Facility	Ward	Type	Coordinates	
				Long	Lat
1	Bukuru Specialist Hospital	Bukuru Central	SHC	484568	1082841
2	Aminci Clinic	Bwandang	PHC	485101	1083745
3	Graceland Clinic and Maternity	Gyel	PHC	483331	1082354
4	Tausayi Clinic and Maternity	Rahwol-Kanang	PHC	484676	1082046
5	Salama Clinic and Maternity	Rahwol-Kanang	PHC	486220	1082030
6	ECWA Comprehensive Health	Bukuru Central	SHC	485448	1083555
7	PHC Bukuru Express	Gyel	PHC	484458	1083354
8	Gyel Central Clinic	Gyel	SHC	482843	1083134
9	COCIN Clinic Gyel	Gyel	SHC	484282	1081995
10	Mushet Nursing and Maternity	Gyel	PHC	484919	1082707
11	PHC Bukuru Central	Bukuru Central	PHC	485268	1082707
12	Veejay Royal Hospital	Bukuru Central	PHC	484610	1082938
13	TCNN Clinic	Rahwol-Kanang	PHC	486925	1082862
14	Medview Radiology	Rahwol-Kanang	SHC	486665	1082664
15	Isban Clinic Bukuru	Bukuru Central	PHC	485293	1082995
16	Abunaeema Clinic	Bukuru Central	PHC	485067	1083082
17	Lokwon Clinic	Bukuru Central	PHC	484449	1082389
18	PHC Gyel	Gyel	PHC	483719	1082636
19	Shopfianol Clinic Takum	Gyel	PHC	483731	1082701

Table 4: Surplus and Deficit of Health Facilities in Bukuru town

Wards	Number of facilities	Projections	Number of PHC	Number of SHC	Surplus PHC	Deficit PHC	Surplus SHC	Deficit SHC
[illegible]	0	20,439	0	0	0	3	0	1
Bukuru Central	7	13,826	4	1	3	0	0	0
Gyel	5	17,452	5	2	0	0	0	0
Kabwir-Kuwang	3	28,766	2	1	0	1	0	0
Ibil	0	12,479	0	0	0	1	0	1
Total	15	113,962	11	4	5	11	0	2

Figure 1: Map showing the distribution of Primary Health Care and Secondary Health Care

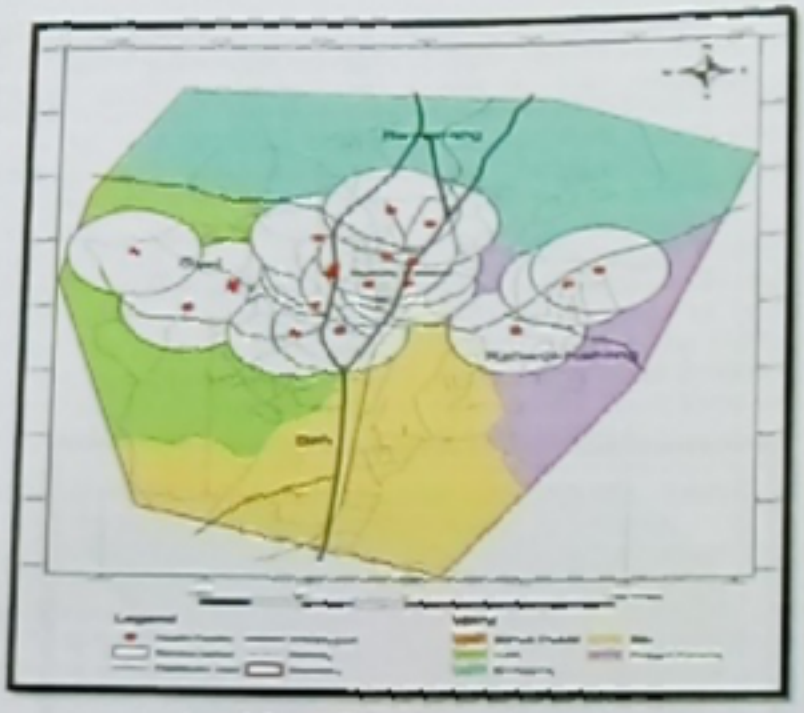

Figure 2: Range of Health facilities in Bukuru town

Problems Facing Health Facility Distribution

Some of the challenges facing the distribution of health facilities in the study area includes low patronage, poor access road, location of the facility while other respondents specified other specific challenges health facilities faced in Bukuru town.

Moreover, the other problems specified by the respondents included; lack of adequate medical equipment's, lack of awareness, low quality staff, poor electricity, poor referral from hospitals, poor staffing and lack of transportation.

The Consistencies of the Identified Factors using Analytic Hierarchy Process

Based on this research, weights were assigned to the four (4) factors or criteria identified; population, service radius, type of health care facility, accessibility. After calculating their consistency ratio, consistency index and running it through a MATLAB program, their overall preference matrix was obtained as presented in Table 5.

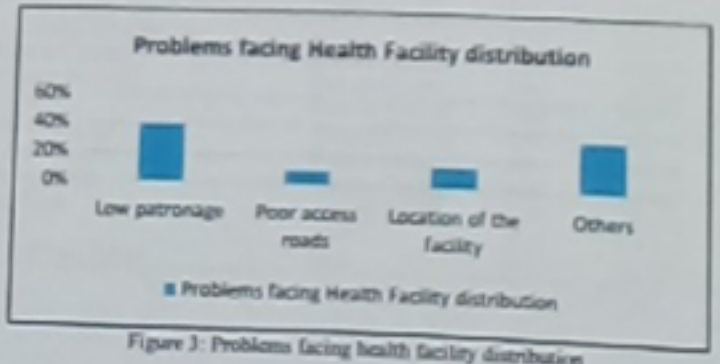

Figure 3: Problems facing health facility distribution

Table 5: Overall preference matrix

Factors	Population	Service Radius	Type of Health Facility	Accessibility	Priority Vectors
Population	1.0000	0.5000	1.0000	1.0000	26.64%
Service Radius	1.0000	1.0000	0.3333	1.0000	15.08%
Type of Health Facility	2.0000	1.0000	1.0000	5.0000	39.34%
Accessibility	1.0000	0.3333	3.0000	1.0000	18.75%
Total	5.0000	2.8000	5.3333	8.0000	100%

The overall preference matrix further shows that the type of health facility has a higher priority vector than all the other factors considered while accessibility has a preference value than all the other factors. Therefore, the AHP preference matrix proposes improvement on the type of health facility in the study area based on access to the facility. Furthermore, this infers that additional health centres should be introduced to cover for the shortage in areas that lack health facilities in other to ensure even distribution of health facilities.

Decision Support Model (Criterion Map)

According to Chakhar and Mousseau (2015), in the spatial context, evaluated criteria are usually associated with geographical entities and relationships between entities, and can be represented in the form of a Criterion map which models the preferences of the decision maker concerning a particular concept. Additionally, a criterion map represents subjective preferential information as seen in Figure 4.

Furthermore, the criterion map shows the most probable areas for locating health facilities which is classified as Poor (Red), Fair (Yellow), Good (Blue) and Very good (Green).

Areas showing Red indicate that the area is not suitable for locating facilities and are mainly water bodies, the seasonal stream, the rail way line and the rocky areas. Yellow means the area can be managed in proposing facilities but these areas are characterised by poor roads, farmlands and little or no settlements while Blue means the area is suitable for locating facilities and is characterised by good roads and adequate utilities and services, and lastly, Green refers to the best areas for proposing health facilities in terms of adequate utilities and services, very good roads and good serene environments with less noise and pollution from road traffic.

Figure 4: Decision Support Model (Criterion map)

Planning Proposals

The recommendations outlined raise spatial distribution strategies that would be fitting to increase accessibility and efficiency towards improving the health needs of the people of Bukuru town. The study is proposing two PHC facilities and one SHC facility in Bwandang in other to cover the needs of the population in Bwandang ward while one SHC facility and one PHC facility were proposed for Bah ward as seen in Figure 6.

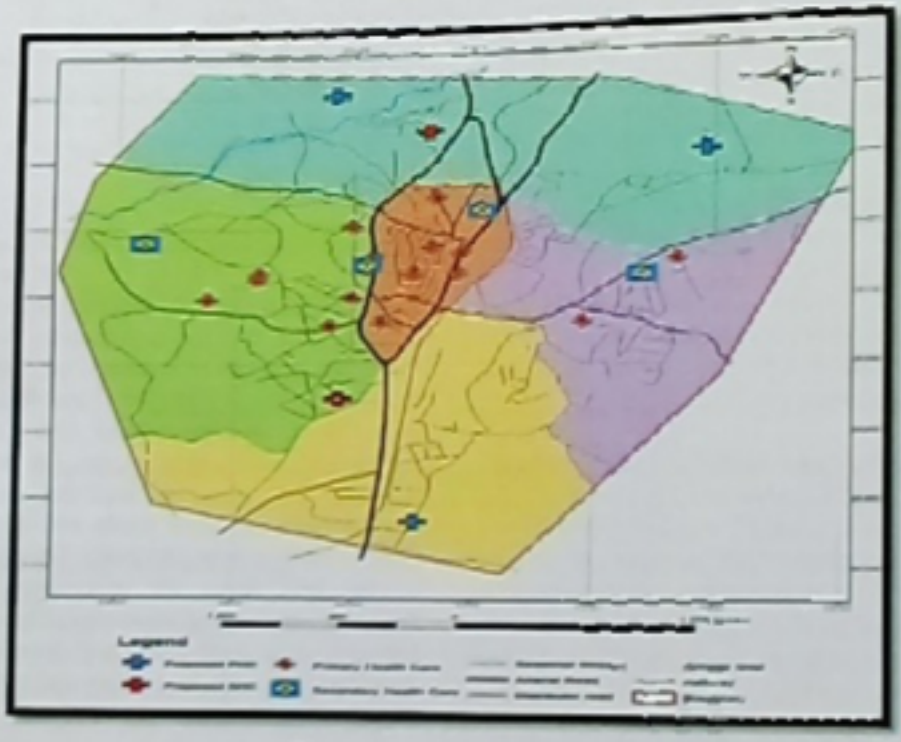

Figure 6: Planning Proposal

Conclusion

The paper exposes the dearth of health facilities in the study area as it can be inferred that 33.6% of the population in the study area are underserved with health facilities. The research concludes that if the proposal is implemented, will reduce the travel time to health centres outside Bukuru town and facilitate determination of different types of health facilities according to prevailing existing conditions. Sense of identification as to defining the specific area of a complete system to the provision of health facilities will be given in the area. Also, policy satisfaction in variety and provision of the health facilities in Bukuru town will equally be attained.

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