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Assessing the Accuracy of GIS Based Multicriteria Decision Analysis for the Location of Health Care Facilities

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Abstract**—** *This research assesses the efficacy of GIS-based MCDA approach in measuring the accessibility of people to healthcare facilities in some selected areas in Lagos state. The research identify factors for location of existing health care facilities in Lagos metropolis, develop multi-criteria for location of health care facilities using analytic hierarchy process of the identified factors and development of hybrid decision support map to guide policy makers decision for the location of health facilities in Lagos based on the multi criteria factors. The data collected using subjective and evaluated questionnaire administered to medical experts and the collection of data on the co-ordinates of healthcare facilities in Lagos state from the Lagos State Ministry of Health. The approach involves integrating one multi-criteria decision in a raster GIS environment, and incorporating the weighted linear combination approach as a method for obtaining the total weights. Based on the generated information, a geo data base was created and the results presented using tables and maps. The results of the research show that; population, income, household size, sewage system, types of healthcare facilities are all consistent factors for the location of healthcare facilities in Lagos state and there is unequal distribution of healthcare facilities which affects the accessibility rate of the health facilities. The research recommends the need for more healthcare facilities and it should be in direct proportion to population.*

I. INTRODUCTION

Increase in global population and incidence of diseases resulting to different health complication has brought about continuous demand for and accessibility to health services resulting to the emergence of two distinct types of accessible index; areas of adequacy with high accessibility and low accessibility index (Grove & Zwi, 2006; Oshitani *et al.*, 2008; Meliala *et al.*, 2013). Inequalities in the geographic accessibility of health care facilities arise as a result of the manner in which people and facilities are arranged spatially (Delamater *et al.*, 2012). Although inequalities in accessibility are inevitable due to this configuration, the extent to which they manifest is a product of the unique spatial arrangement of the health care delivery system, the location and distribution of the population within a region. Particular concern are scenarios that result in large distances between people and health care facilities (Dummer, 2008).

The challenge of accessing health care facilities has strong correlation with difference in economic status as well as disparities in level of technology among difference nations of the world (Peters *et al.*, 2008). In developed world like; United State (US), China, Japan have significantly reduced the accessibility index of it populace to a minimum level irrespective of economic status, third world countries are far lag behind with poor accessibility index (Van Doorslaer *et al.*, 2006; Osungbade *et al.*, 2008; Nnebue *et al.*, 2014; Asa *et al.*, 2015) (Odeyemi & Nixon, 2013; Adedini *et al.*, 2014; Adebowale & Udjo, 2016). Where minimal index is achieved, the existing facilities is often characterized by inadequate qualify health care personal, poor economic status and politicizing of the entire health sector development policies resulting to ill health of the nation (Peters et al., 2008).

Nigeria with it health care facilities hovering over 600 thousand including public, private and primary health care (Eggers & Macmillan, 2013), is characterize by; inadequate personal, lack of adequate supervision, poor policy development implementation, lack of equipment and poor accessibility index resulting to many avoidable death from curable disease (Organization, 2006) .

Baker and Liu (2006); Olusanya *et al.* (2006); (Levesque *et al.*, 2013); McGrail and Humphreys (2014); Tao *et al.* (2014); Blumenthal and McGinnis (2015); Neutens (2015) researches evaluated and developed a model through which accessibility to health care facilities could be evaluated with appealing results. However, utilization of these facilities based on demand and vulnerability has failed far below the invested resources and output potentials of these investments. Thus, the need to integrate these intricate factors into a singular model that is capable of processing multi layer information from diverse sources if low accessibility index is to be achieved. Geographical Information System (GIS) model developed by (Lovett *et al.*, 2002; Black *et al.*, 2004; Higgs, 2004; Pearce *et al.*, 2006; Tanser *et al.*, 2006) focused on monovariate parameter making decision regarding location of healthcare facilities complex to come by. Most of the monovariant approach often utilizes parameter such as, travelling time, mode of transport, population, epidemiology of disease, mapping of disease vulnerable areas , efficacy and suitability of health care facilities types in a given location which can effectively be integrated and managed as a multilayer information in a GIS environment for enhanced decision making (Watkins *et al.*, 2007; Gao *et al.*, 2008; Notenbaert *et al.*, 2010).

GIS based Multi Criteria Decision Analysis (MCDA) approach provide a guide through which policy makers and other stake holders can effectively site health care facilities with high level of accessibility based on needs (Higgs, 2006)

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in view of the current economic uncertainties and continues increase in population. Spatial decision and accessibility related problems, are large set of feasible alternatives, multiple conflicting and incommensurable evaluating criteria are always involved (Malczewski, 2006). These alternatives are evaluated by a number of individuals (decision makers, manager, stake holders, and interest groups).

MCDA has been integrated with GIS for effective decision making (Linkov *et al.*, 2006; Malczewski, 2006) with wide application in; modeling the location of new services (Yatsalo *et al.*, 2007; Feizizadeh *et al.*, 2014; Malczewski & Liu, 2014; Singh *et al.*, 2017); participatory design to develop (public) health decision support systems; (Igor *et al.*, 2006; Driedger *et al.*, 2007; McLafferty *et al.*, 2007; Lyseen *et al.*, 2014; Malczewski & Liu, 2014), detecting flood susceptible areas; (Kolat *et al.*, 2006; Lawal *et al.*, 2012; Pourghasemi *et al.*, 2014; Dehe & Bamford, 2015; Malczewski & Rinner, 2015b), making good decision in healthcare;(Mamdani & Bangser, 2004; Dimitrova *et al.*, 2006; Légaré *et al.*, 2010; Ahmad, 2012; Hunink *et al.*, 2014), environmental health among several others.

This research implement MCDA using AHP in assigning weight to health related factors to guide policy makers on appropriate location for health care facilities towards a healthy society and sustainable development while minimizing resources. The technique enhance decision making and analysts combine multiple factors perceived to influence the occurrences of certain events, and it typically results in 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.

A. Application of GIS in MCDA

Numbers of approach that define decision problems in MCDA is suggested by Malczewski (2006); Mendoza and Martins (2006). At the most rudimentary level, a multi-criteria decision problem involves a set of alternatives that are evaluated on the basis of convicting and incommensurate criteria according to the decision maker's preferences. There are three key terms in this defination which are the main elements of any MCD problem decision maker(s), alternatives, and criteria (Triantaphyllou, 2013). The procedures for tackling spatial multi-criteria problems involve three main concepts: value scaling (or standardization), criterion weighting, and combination (decision) rule (Drobne & Lisec, 2009; Boroushaki & Malczewski, 2010). These are fundamental concepts for MCDA in general and GIS-MCDA in particular. Many spatial decisions are made by groups (multiple decision makers) rather than an individual decision maker. The degree of consensus can be considered a major determinant of the nature of the decision making process (Massam, 1993). Consequently, the distinction between individual and multiple decision makers rests less on the number of individuals involved than on the consistency of the group's goals, preferences, and beliefs (Mendoza & Martins, 2006) .If there is a single goal-preference-belief structure, then one is dealing with individual decision making, regardless of the number of individuals actually involved. On the other hand, if any of these components varies among the individuals constituting the decision making group, then we are coping with group decision making (Malczewski & Rinner, 2015a).
While the conventional decision analysis focuses on the human decision maker, the recent approaches to computer-based modeling provides a broader description of decision maker including the concept of decision making agents (Parker *et al.*, 2003; Sengupta & Bennett, 2003; O'Sullivan & Unwin, 2010). Furthermore, humanistic characteristics such as preferences, beliefs, and opinions can be a part of agent behavior. These characteristics make it possible to represent human decision making as agents acting in a simulated real-world environment Raja and Renée (2007); Boroushaki and Malczewski (2010) provide a comprehensive overview of geospatial agents and identify two general uses of the term in GIS with implementation in Rinner and Taranu (2006).

B. Aim and Objectives of the Study

The aim of this research is to assess the effect of GIS based MCDA on the accessibility of healthcare facilities in some selected areas in Lagos state with the following objectives;

i. To identify factors for location of existing health care facilities in Lagos metropolis.
ii. To develop multi-criteria for location of health care facilities using analytic hierarchy process of the identified factors.
iii. To develop hybrid map of health facilities in Lagos based on the multi criteria factors.

II. METHODOLOGY

A. Data Collection

The data required for this research was obtained primarily from designed questionnaires administered by medical experts. The data collected from this source was used to make decisions using the Analytical Hierarchy Process (AHP). These data were categorized to show the level of importance of the socio-economic factors affecting public health.

In order to determine the locations of some healthcare facilities in Lagos State, data on the Co-ordinates of healthcare facilities in Lagos State was collected from the Lagos State Ministry of Health

B. Selecting the Criteria/Factors Influencing Public Health in the Study Area

The factors that were considered in this research were population, income, household size, sewage system, type of health care facilities and socio-economic factor. Due to their critical role in determined accessibility to health care facilities and hence critical to location in health care services in an area.

C. Questionnaire

A total of six questionnaires were used for this research with each of the questionnaires containing the factors affecting public health and each factor are weighted according to their

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level of relevace using Saaty's scale. The questionnaires were administered to medical experts (consultant) for evaluation of the weight assigned to each of the parameters understudy.

D. Weight Assignment and Calculation of Comparison Consistency

The weight of each factor was determine 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 table I in order of relative importance role contributing to aquifer water yield potential. Pair wise comparison matrices of the assigned weights of the map themes along with the individual features were normalized to obtain the Eingen vector as shown in table II. The Eigen vector values for each of the map themes were determine using Matlab 2010a. The pair wise comparison represents relative importance of the factors under study.

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

$$CI=\frac{\lambda max-n}{n-1} \quad (i)$$

Where n=number of factor, λmax = consistency or Eigen value.

The consistency ratio (CR) was determined using the relation

$$CR=\frac{CI}{RI} \quad (ii)$$

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

E. Data Analysis Technique

Figure 1 is the summary of the methodology used in this research. Criteria for the identified weight were selected proportional to the perceived influence on the need to health care facilities in an area. Data related to existing health care facilities as well as environmental quality and hygienic information was obtained from the Lagos state Ministry of health and environment respectively. The generated information was prepared and integrated into the built geo data base. The consistency ratio was determined from six (6) identified and evaluated parameters by a qualified and licensed medical consultant. Based on the evaluated parameter, a pair wise comparison of 6×6 matrix was developed and run in Matlab 2010 application. The pair wise comparison matrix output was used to generated the consistency ratio and index.

TABLE I. 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 strongly	extremely
1/9	1/7	1/5	1/3	1	3	3	7	9

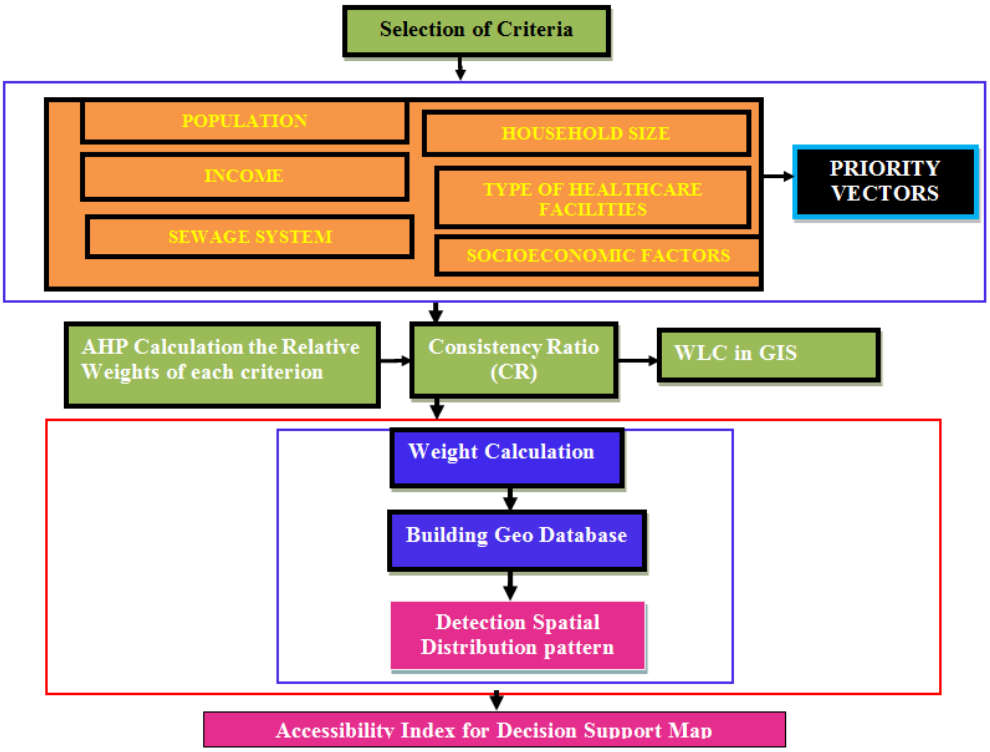

Fig. 1. Methodology employed in the research.

F. Location of Lagos

Lagos is located in the South-Western part of Nigeria; between longitude 2°45'00" to 14°67'88" and latitude 4°27'30" to 13°89'44" North of the Equator. It has a coverage area of 335,000 hectares (3,350sq.km). Lagos is bounded to the south

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by the Atlantic ocean to the North by Kwara and to the west by Ogun state as depicted in Figure 2

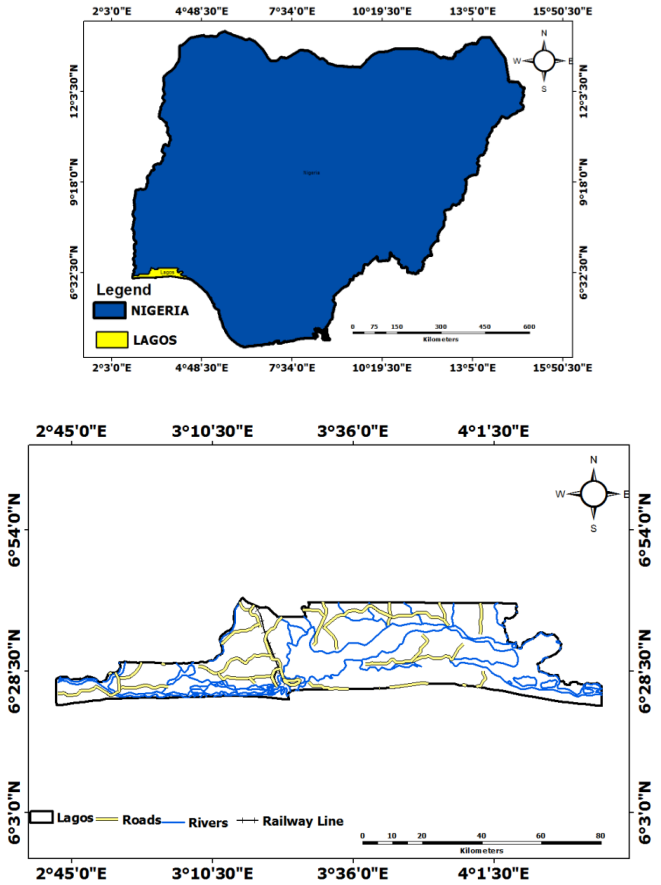

Fig. 2. Map of the selected local government areas of Lagos state.

III. Results and Discussion

Based on this research, six (6) factors were identified; population, income, household size, sewage system, types of healthcare facilities and socio-economic factors with overall preference matrix as presented in table II.

TABLE II. Overall preference matrix.

F	P	I	HS	SS	THCF	SEF	PV
P	1.0000	1.0000	0.5000	1.0000	1.0000	0.5000	12.53%
I	1.0000	1.0000	1.0000	1.0000	0.3333	1.0000	14.49%
HS	2.0000	1.0000	1.0000	1.0000	1.0000	5.0000	26.81%
SS	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	19.62%
THCF	1.0000	0.3333	1.0000	0.3333	1.0000	1.0000	12.18%
SEF	2.0000	1.0000	0.2000	1.0000	1.0000	1.0000	14.37%
Total	8.0000	5.3333	4.7000	5.3333	7.3333	9.5000	100%

F: Factors, **P**: population, **I**: Income, **HS**: Household Size, **SS**: Sewage System, **THCF**: Type of Health care Facilities, **SEF**: Socioeconomic Factor and **PV**: Priority Vector

A. Population

Population is the total number of people living in a geographical region. Population is one of the factors that is considered when locating a healthcare facility (Arcury *et al.*, 2005). The larger the population of a local government, the larger the numbers of healthcare facilities provided. This statement is true within the context of developed world. However, in developing and under developed world characterized by high population density, poor income level, large family sizes have sparsely distributed health care facilities. Thus, accessibility becomes a matter of cost and affordability.

In this research as depicted in Figure 4. Ikorodu has a population density of 435 with HCF of 124 is expected to have the highest accessibility index compare to Oshodi with a population density of 70 and existing HCF of 117. However, Epe has the lowest HCF of 25 and population density of 500. Epe therefore is expected to be an area that is critically in need of additional HCF if healthy living and relatively disease free society is to be attained. In achieving this recommendation and consideration in terms of needs need to be priorities over any other sentiment or political influence. In addition, hygienic and economic conditions need to be augmented through appropriate policy formulation.

B. Income

Income influences the location of healthcare facilities due to the need of capital to provide a standard healthcare facility. Also, low-income people, especially living in rural areas tend to have low access to healthcare facilities. Low income people are publicly insured in plans enabling them to get primary care services in public primary healthcare facilities (Starfield & Shi, 2004). High income people tend to obtain their full set of healthcare facilities housed in hospitals. Middle income people can choose to either public or private health centers.

Additionally, for middle income people, income could be an important predictor of choice of healthcare facilities since out of pocket expenses tend to be higher than for high income people that are able to buy health plans with better benefit packages (Listl, 2011). In some developing countries in Africa, the low expenditure on health has affected the provision of physical and consumable health facilities. Low income makes quality care inaccessible to a greater proportion of the population.

C. Household size

The household size has direct relationship with the location of healthcare facilities. This implies that an increase in household size increases the awareness to the government to provide more healthcare facilities. Larger household sizes would spend more of the available household income on the food needs of the family. This makes the choice of government hospitals for such households. Studies show that those with large household size have the highest health service utilization (Idler & Benyamini, 1997; Chakraborty *et al.*, 2003; Arcury et al., 2005).

While utilization of modern health facilities decreases with household size, utilization of traditional health care facilities increases with household size. Most of the households with few members utilize government hospitals while of households with large member's utilized self-care and traditional care respectively. The result further shows that private hospitals are least utilized in the rural area probably

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because of high cost of consultation. It can be deduced that larger sized households may not be able to afford modern health facilities and thus turn to the utilization of self-medication and traditional health care services, which they consider relatively cheaper as a larger share of household expenditure will be spent on food.

D. Sewage System

In areas with poor sewage system due to aging infrastructures, poor installation of infrastructures or lack of infrastructures, and availability of poor drainage system, such as rural areas, healthcare facilities are located in such areas so as to provide easy access in case of disease outbreak (Świątek *et al.*, 2013).

E. Types of Healthcare Facilities

Healthcare facilities encompass a wide range of types, from small and relatively simple medical clinics to large, complex and costly, teaching and research hospitals (Scott, 2000). In a region that lacks one type of healthcare facility, it is usually located in such areas. In areas where private healthcare facilities are mostly occupied, more public facilities are provided to save costs and gain easy access. Low income people tend to utilize public health facilities than private health facilities (Wagstaff, 2002). This is because they cannot afford expensive health services due to their low income. They spend greater part of their income on food.

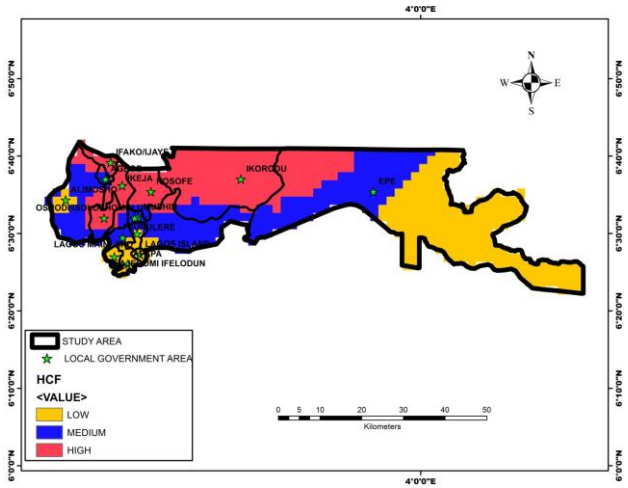

Fig. 3. Healthcare facilities map of the selected study area.

F. Socio-Economic Factors

Socioeconomic status is a multidimensional concept; among the dimensions typically associated with socioeconomic status (SES) are occupational status, educational achievement, income, poverty, and wealth etc (Krieger *et al.*, 2003). In many societies whether rich or poor, those of greater privilege tend to enjoy better health than their counterpart. According to Abodunrin *et al.* (2010), the choice of health facilities for healthcare by an individual is largely determined by his/her taste, satisfaction with service and the perceived quality of care provided, the choice is however limited by factors such as availability, accessibility, affordability of services of the health facilities, cultural beliefs, the situation per time (i.e. urgency of care needed) and whether the kinds of services provided meet the need of the user. They further opined that the choice is also influenced by the users'understanding of the functions of the different levels of health facilities which ultimately result in the appropriate (or otherwise) utilization of health services. In Nigeria, healthcare system comprises both public and private health facilities.

The socio-economic status of a country will most likely reflect the health situation, generally, the better the economy indicators, the better the health condition. According to Organization (2000), in some developing countries in Africa, the low expenditure on health has affected the provision of physical and consumable health facilities. Low wages makes quality care inaccessible to a greater proportion of the population. Economic factor is seen as affecting the availability of treatment, when the cost of treatment rises above what an individual can pay or above what he considers appropriate for the perceived seriousness of the illness, then that form of treatment effectively becomes unavailable to such a person.

G. The Consistencies of the Identified Factors using Analytic Hierarchy Process

The total weights assigned to the six selected factors are presented in Figure 4. The process of obtaining normalized weights by analytic hierarchy process (AHP) and eigenvector techniques is presented in Appendix V. From Figure 4, Kosofe appeared to be the only area that has good accessibility index from the identified factors. Ikorodu, Ikeja, Oshodi and Surelere among other correspond to local government with good accessibility index to HCF while the less remaining local government area were identified to have fair accessibility to HCF.

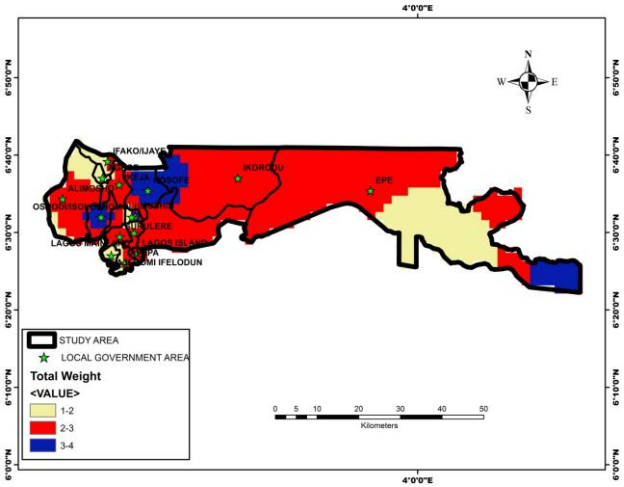

Fig. 4. Total weights of the selected factors.

According to National Population Comission (2006), Lagos has a population of 9.1 million people and is expected to double this figure by 2020 (Kennedy, 2011). The high population index is expected to generate large amount of waste due to demand for resource satisfaction thereby, degrading the quality of the environment with adverse effect on the potential for disease outbreak. In view of this projected

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population and the result of this research the need for a sustainable planning to meet the population demand for HCF becomes necessary in line with vision 2020 of conquering many of the environmental related diseases and life threatening ill-health through provision of adequate HCF. To achieve this vision, development of quality, highly efficient, effective and reliable model that guide Policy makers, stake holders and government in citing of HCF in area is critical for sustainable development of the state and Nigeria at large.

H. Decision Support Guide for Location of Health Care Facilities in Lagos

Figure 4 is the developed decision support model from the AHP and priority vector for the location of HCF in Lagos based on the weights of the multi-criteria factors. The map shows the level of the availability of healthcare facilities in some selected areas of Lagos State. Based on the total weights, the study area can be divided into three classes, fair, good, and very good as shown in Figure 4 where the minimum weight is 1.7898 and the maximum is 3.6199. Very few areas have enough healthcare facilities, most part of the selected study are has good number of healthcare facilities while the number of healthcare facilities in the remaining few are considered as being fair.

Accessibility to healthcare facilities in Epe Local Government vary such that some has very good access, some have good access while some have fair access to healthcare facilities. Areas such as Ikorodu, Lagos Mainland, Apapa, part of Epe, Ajeoromi/Ifelodun, Ikeja, Oshodi/Isolo and Alimosho have good access to healthcare facilities,areas such as Kosofe, Part of Epe, Mushin, Shomolu and Lagos Island have very good accessibility to healthcare facilities while places like Surulere, part of Epe, and Agege have a fair access to healthcare facilities. It was also discovered that the urban areas have more accessibility than the rural areas.

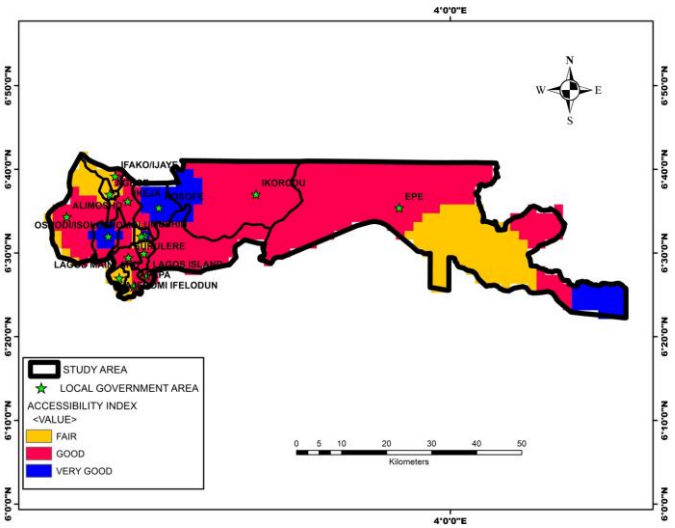

Fig. 5. Accessibility index of the selected study area.

IV. CONCLUSION

This research has shown that there is uneven distribution as well as average level of accessibility to healthcare facilities in Lagos state. It has assessed the effectiveness of GIS-based MCDA as a spatial decision making tool especially in healthcare. The availability of sufficient healthcare facilities is extremely important to control disease outbreak and save lives. The ability to determine the spatial distribution of people and places on the earth surface and to make judgments on basic factors if the key element to using GIS-based MCDA. By using this spatial decision making tool, government stand a chance of knowing the areas that need more healthcare facilities and helping the population have a good and healthy living.

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