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Research Paper

Road Network Accessibility to Healthcare Facilities Using Geospatial Techniques In Delta State, Nigeria

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ABSTRACT
The need to meet the service requirements of the growing population is vital to the success of the Government's commitment to sustainable mobility. Recent advances in the field of health geography have greatly improved our understanding of the role played by geographic distribution of health services. This paper evaluates the road network accessibility to healthcare facilities using geospatial techniques in Delta State. In developing the research design, areas that are accessible to the road networks and with population of 10,000 and above was taken as activity centres. Based on the adopted operational definition of major centres, 50 major centres were identified. The result shows that there is some relationship between travel time and cost factors and distance. It was also found that there is generally some relationship between link distance and travel cost. The correlation coefficient was calculated to be 0.86. furthermore, using simple regression analysis, it was found that road distance accessibility was found to be more significant factor in the occurrence of health facilities in the study area. Based on the findings, the study is recommended as a spatial decision support systems for policy makers regarding accessibility of healthcare facilities in Delta State in particular and Nigeria in general.
KEYWORDS*: Accessibility; healthcare facilities; geospatial; road; policy makers; sustainable mobility; Delta State*

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I. INTRODUCTION

A considerable research effort has been devoted to road network planning models over the last forty years. The vast majority of these efforts were oriented towards two models; the discrete network design problem (DNDP) model and especially, the continuous network design problem (CNDP) model. The former focus on the addition of new links to a road network, whereas the latter concentrates on the (continuous) expansion of capacity of existing links. Both models are built around an efficiency objective typically the maximization of user benefits or the minimization of user costs. Among the best known articles where these models are dealt with one may quote LeBlanc (1975) and Boyce and Janson (1980) regarding the DNDP model and Abdulaal and LeBlanc (1979), Leblanc and Boyce (1986), Suwansirikui et al (1987) and Friesz et al (1992), regarding the CNDP model, for a relatively recent review of this literature, see Yang and Bell (1998), and Atubi (2012f, 2019 and 2019b).

In those countries where the basic road network is incomplete it will usually be appropriate to adopt a relatively low level of geometric standards in order to release resources to provide more basic road links. This policy will generally do more to foster economic development than building a smaller number of road links to a higher standard (Transport and road Research laboratory, 2006). In an attempt to satisfy this high degree of spatial interactions, transport system has been provided on a large scale and various model of transport have been developed. Thus, rail, road, sea and air routes have been developed to move people and goods; pipelines to move oil, water and natural gas and overhead cables to move information and render other services. The development of these modes of transport provides the various transportation networks and as Toyne and Nawby stated "network may be regarded as geographical features underlying the whole of human and economic activity; without them there can be neither movement, change, development nor function, all of which are the fundamental pre-requisites of activity of any kind" (Toyne and Newby, 2004, p. 173).

One of the goals of regional planning is to ensure that infrastructural facilities necessary for development are made accessible to as many people as possible within the region. One way that planners have tried to meet this goal is the establishment of growth centres or poles where facilities are concentrated with the hope that the benefits of concentration will gradually trickle down to the surrounding areas.

However, Brain and Rodney (2009) observed that the comparatively low levels of economic activity in many of the less developed countries is often reflected in the modest scale of their transport systems.

Spatial accessibility has become a pre-requisites to the integration of the urban centre and its circumference (Cao and Yan, 2006). The spatial evolution of metropolitan area and of its transport network are in interactive process (Wang and Jim, 2005). A well-developed transport network has become the basic condition and essential pre-requisites to the systematic operation of the whole metropolitan area, the accessibility of which determines whether or not the material flow, the energy flow as well as the information flow is smooth between the urban centre and its circumference.

Through accessibility analysis, the interactive degree between the urban centre and its circumference can be well reflected (Hansen, 2013). So are the exchange opportunities and potentiality in social, economic, cultural and technology sections between the two parts, and it is the focus of current researching field that revealing the geo-spatial characteristics of the metropolitan area and analysing and evaluating the spatial structure of that by studying its transport network and spatial accessibility between the urban centre and it circumference (Hodge, 2009).

It is essential to appreciate that the purpose of transport is to provide accessibility, or the ability to make a journey for a specific purpose. Transport is not consumed for its own sake, but is merely a means to an end (a derived demand) Hoyle and Knowles, 2004).

However, studies of accessibility are more concerned with issues of efficiency and equity with respect to location of public facilities. An efficient location of public facilities is defined as that which gives the minimum total systems cost of operation and travel of a given level or volume of service. Equity in location of public facilities on the other hand is one which promotes greater equality of conditions (Rich, 1979; Pasguale, 2009 and Paul et al, 2012).

Since accessibility is the ultimate goal of most transportation activity (excepting the small amount of travel that has no desired destination), transport planning should be based on accessibility. However, conventional planning tends to evaluate transport system performance based primarily on motor vehicle travel conditions using indicators such as roadway level-of-service, traffic speeds and vehicle operating costs, other accessibility factors are often over looked or undervalued. This tends to favour mobility over accessibility and automobile transport over other modes. Many of these planning biases are subtitle and technical, resulting from the statistics used to measure travel demands, the selection of performance indicators, and the formulas used to allocate resources (Udo et al, 2008; Susan et al, 2008; Chao et al, 2010 and Robert, 2011).

In Nigeria, several studies on accessibility tend to be related to urban centres or urban based activities. Thus Weinnand (1973); Mohammed &Dahuasi, 2013), in a study of development in Nigeria observed that spread effects of concentration of development are limited to the vicinity core areas while much of the periphery is virtually immuned to development impulses. This finding is supported by other studies from other developing countries (Robinson and Salih, 1971; Gilbert, 1975; Roger et al, 1999; Bertohini, 2003).

From the past studies in Nigeria, it was observed that the emphasis tends to be either on urban centres (Onokerhoraye, 1976), postal services (Oherein, 1985), banking (Soyode et al, 1975), bus transport services (Ali, 1997) access to facilities, Atubi, (1998). There is however a need to take a total view of transport in terms of the various activities for which the users demand mobility (Jansen, 1978).The relevance of this paper is this total view. It considers access to the major centres in the study area as well as health facilities within the context of central functions provided in a particular area.

Study Area

Delta State is located between longitude 5°00’ and 6°45’ East and latitude 5°00’ and 6°00’ North in the Niger Delta region of Nigeria (See Fig. 1), with a total land area of 18,050 sq.km and an estimated population of 4,112,445 people (National Population Commission, 2006). The state is one of the frontline oil and gas producing states in the Niger Delta. It shares several common characteristics with other states in the Niger Delta region, with its development landscape and outcomes being paradoxically at variance with the quantum of natural resources available in the region. However, the population of Delta State in 2019 was estimated at 5,519,826 with an annual growth rate of 3.3%.

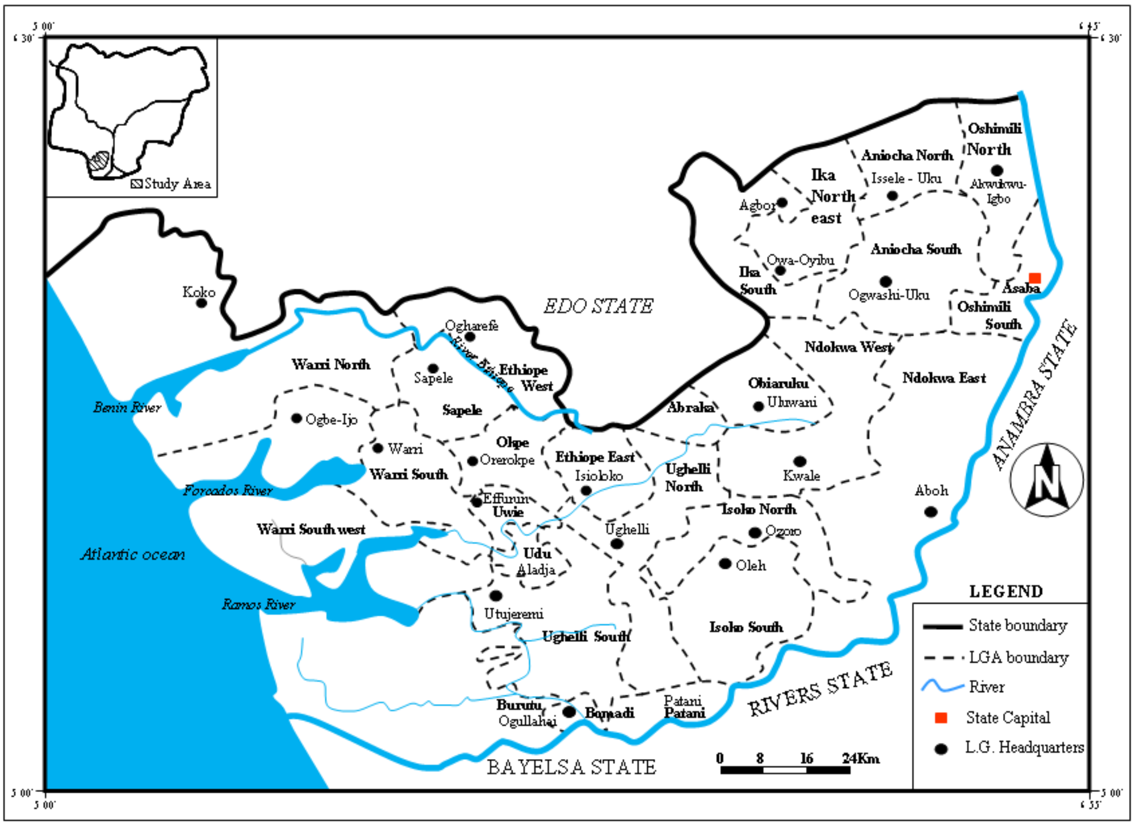

FIG 1: MAP OF DELATA STATE SHOWING STUDY AREAS

II. RESEARCH METHODS

The research is concerned primarily with a study of road transport network, in Delta State as it relates to relative accessibility of centres. In developing the research design areas that are accessible to the road networks and with population of 10,000 and above were taken as activity centres. The choice of nodes was therefore based on population size. Based on the adopted operational/definition of major centres, 50 major centres were identified.

In order to classify the major centres, data on health facilities provision was collected. The choice of this facility was based on the fact that it is capable of generating home-to-facility travels.

Following Singh (1979) we considered both the number of establishments for each type of function to reflect functional distinctiveness. With this procedure, the existence of more than one hospital in a particular centre will reflect a higher order centre than the existence of only one. In addition, the facility will be weighted to reflect the range of services offered at each level of hierarchy. This illustration of the number of facility or functions considered along with the score is shown in Appendix A. The weighting system follows closely that of Atubi (1998) by attaching 10 to first order function, 5 to second order and 1 to-third order function. To ascertain if a relationship exists between accessibility and functional index of health facility occurrence in the study area, Pearson's Product Moment Correlation Coefficient statistics (r) was employed as well as the students't' test.

III. DISCUSSION OF RESULTS/FINDINGS

At the end of 2015, there were about 1710 recognized health institutions with a total of 6443 beds throughout Delta State (Delta State Ministry of Health, Asaba, 2015). According to state ministry of health, healthcare facilities are grouped into special health facilities and basic health facilities. The special health facilities include all hospitals, special units, public health laboratories and health training institutions. The basic health facilities on the other hand are of local importance. They include health centres, maternity homes and dispensaries.

The institutions are owned by either government (Federal, State and Local Governments), voluntary agencies (especially missions) or by the private sector. The state government owns about 54 hospitals in Delta State with at least one in each Local Government Area. And these are directly managed by the hospital management board which for administrative convenience, has been grouped under eight medical zones. These are Agbor, Asaba, Akwukwu-Igbo, Bomadi, Kwale, Ogwashi-Uku, Ole, Sapele and Warri medical zones. Out of the 54 hospitals four (4) with 100 beds each, have been designated central hospitals (Warri, Sapele, Ughelli and Agbor central hospitals), state hospital in Local Government headquarters are called general hospitals, while those sited in places other than LGA headquarters and which generally have 30 beds capacity each are known as government hospitals. There are many primary health centres (PHC) (538 maternal health centres, medical health centres, and maternity homes) run by the local government councils which complement the effort of the state government to bring health care delivery services. Also, there are numerous private hospitals and clinics (over 1109) that runs 24 hours health services in Delta State. Added to the above, is the Delta State university teaching hospital located at Oghara in Ethiope west Local Government Area and the Federal Medical Centre located at Asaba the state capital.

In terms of spatial distribution Fig. 2 reveals the pattern of health institutions. It can be said that Delta central senatorial zone (Ughelli North, Ughelli South "Uvwie, Ethiope East, Ethiope West, Okpe and Udu) and Delta North senatorial zone (Aniocha south, Ika North east, Ndokwa north east, Ukwani, Oshimili south and Ika South) Local Government Areas had the highest concentration of health institutions in Delta State. Another area of concentration is Warri South West, Uvwie, Ika South Oshimili South and Ughell North Local Government Areas which has the largest number of private facilities in Delta State. The peripheries of Ndokwa East, Patani and Warri North have relatively lower concentration of public health institutions.

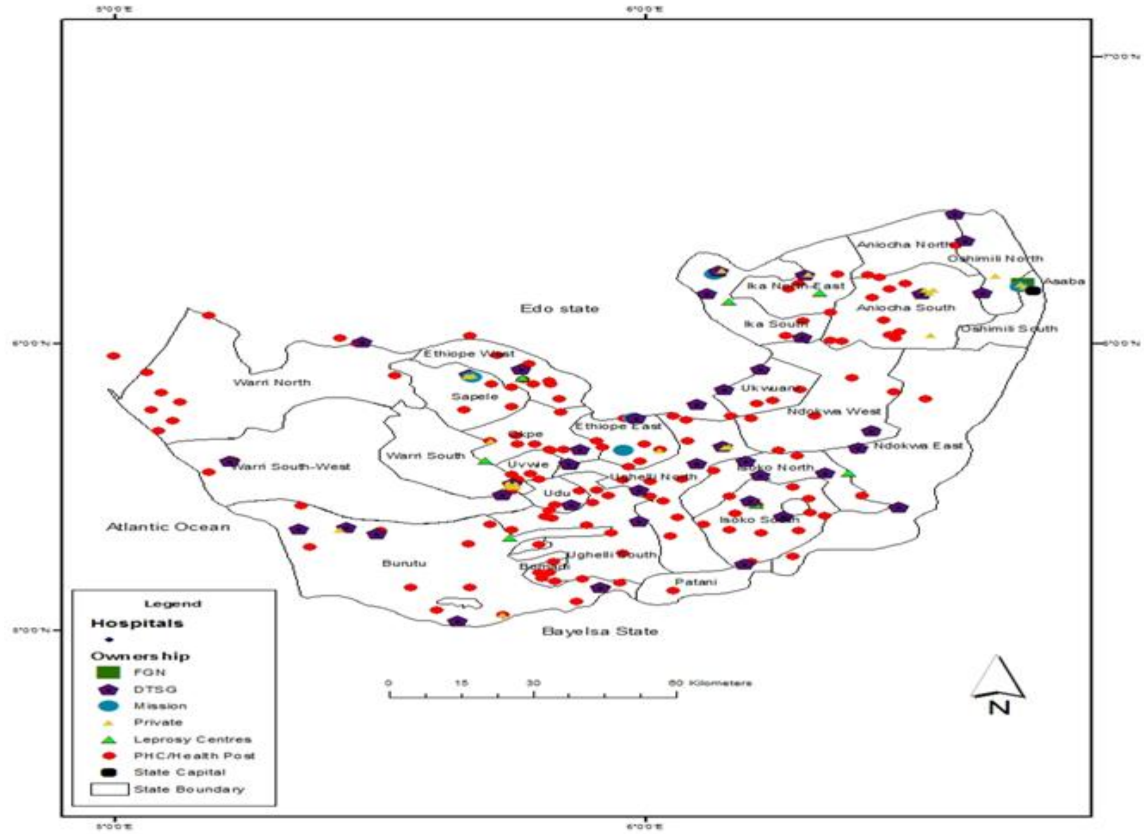

Fig. 2: Distribution of Health Institutions in Delta State

Apart from merely establishing a hierarchy of central places, ordering of facilities can be used to construct an index of modernisation as in Soja (1968), Gould (1970), Leinbach (1976), Onakorhoraye (1982 and Atubi 2012c, 2019).

However, having weighted the function, the product of the number of establishments of each function and the weight is summed up for a centre to give functional index of facility occurrence (See Appendix A). This index shows the level of concentration of facilities in that centre.

Table 1 gives the calculated indices for the 51 centres of the study area.

Table 1: The functional index of facility occurrence in Delta State 2016

S/N	Mode No.	Population 2006 Census	X1		X2		X3		X4		Functional Index Total
			UNF	WV	UNF	WV	UNF	WV	UNF	WV	Weight
1	Issele-uku	32101	0	0	2	12	1	2	0	0	**17**
2	Ogwashi-Uku	63080	0	0	2	10	2	4	0	0	**18**
3	Owa-oyibu	73000	1	10	1	5	3	6	0	0	**26**
4	Agbor	84020	1	10	10	50	2	2	0	0	**75**
5	Ashaka	41330	0	0	1	5	0	0	0	0	**6**
6	Kwale	54064	0	0	1	5	2	2	0	0	**10**
7	Ibusa	64231	0	0	3	15	0	0	0	0	**18**
8	Asaba	106020	1	10	15	75	0	0	0	0	**101**
9	Obiaruku	46231	0	0	3	15	0	0	0	0	**18**
10	Abavo	23010	0	0	1	5	0	0	0	0	**6**
11	Umuebu	11091	0	0	1	5	0	0	0	0	**6**
12	Bomadi	23072	0	0	3	15	1	2	0	0	**21**
13	Burutu	93224	1	10	4	20	1	2	1	1	**40**
14	Ozoro	74222	1	10	1	5	1	2	0	0	**20**
15	Oleh	102701	1	10	5	25	1	2	0	0	**44**
16	Patani	26021	0	0	1	5	0	0	0	0	**6**
17	Koko	101232	0	0	1	5	4	8	0	0	**18**
18	Warri	201642	1	10	70	300	0	0	0	0	**381**
19	Ogbe-ijo	88103	0	0	1	5	1	2	0	0	**9**
20	Ogidigbeu	15021	0	0	0	0	1	2	0	0	**3**
21	Omadino	23741	0	0	0	0	0	0	1	1	**2**
22	Uzere	52061	0	0	1	5	1	2	0	0	**9**
23	Kiagbodo	98201	0	0	1	5	1	2	0	0	**9**
24	Abraka	86224	0	0	10	50	1	2	0	0	**63**
25	Oghara	103060	2	20	4	20	0	0	0	0	**46**
26	Orerokpe	68021	0	0	6	30	0	0	0	0	**36**
27	Sapele	92101	0	0	10	50	0	0	0	0	**60**
28	Otor-utu	101221	0	0	3	15	0	0	0	0	**18**
29	Ughelli	183201	0	0	8	40	0	0	0	0	**48**
30	Otu-jeremi	104231	0	0	5	25	0	0	0	0	**30**
31	Effurun	101021	0	0	40	200	0	0	0	0	**240**
32	Isiokolo	34010	0	0	3	15	1	2	0	0	**21**
33	Jeddo	16201	0	0	1	5	0	0	0	0	**6**
34	Oria	18220	0	0	0	0	0	0	0	0	**0**
35	Eku	241221	0	0	1	5	0	0	0	0	**6**
36	Aviara	29010	0	0	1	5	0	0	0	0	**6**
37	Kokori	30071	0	0	2	10	0	0	0	0	**12**
38	Adagbrasa	19772	0	0	1	5	0	0	0	0	**6**
39	Aladja (DSC)	31010	0	0	10	50	1	2	0	0	**63**
40	Ewu/Urhobo	161222	0	0	1	5	1	2	0	0	**9**
41	Forcados	12990	0	0	1	5	1	2	1	1	**11**
42	Igbodo	13030	0	0	1	5	0	0	0	0	**6**
43	Illah	18241	0	0	1	5	1	2	0	0	**9**
44	Obior	12080	0	0	1	5	1	2	0	0	**9**
45	Orogun	16209	1	10	1	5	0	0	0	0	**17**
46	Okpara	41090	0	0	2	10	0	0	0	0	**12**
47	Olomoro	29330	0	0	1	5	1	2	0	0	**9**
48	Onicha-ugbo	22410	0	0	1	5	0	0	0	0	**6**
49	Ononta	16020	0	0	1	5	0	0	0	0	**6**
50	Umunede	28090	0	0	1	5	1	2	0	0	**9**
51	Umutu	26220	0	0	1	5	0	0	0	0	**6**

UNF = Un-weighted number of facilities, WV = Weighted value

Source: National Population Commission and Fieldwork, (2016)

X_1 = Specialist hospital

X_2 = General + private hospitals

X_3 = Health centre + Maternity homes

X_4 = Dispensary

An analysis of correlation between the various variables was carried out while its significance (whether it is a chance occurrence or not) is tested by means of the t-test. Appendix B gives a pair wise correlation matrix of the 4 variables employed in the index construction. The analysis reveals a certain pattern of association. For example, it is seen that the occurrence of specialist hospital (X_1) is highly associated with occurrence of general/private hospitals (X_2) and health clinics/health centres/maternity homes (X_3). At the other extreme, is the occurrence of dispensaries (X_4) which has negative association with most of the variables. This implies that whereas specialist hospitals, health centres/maternity homes and general hospitals are found in higher order centres, dispensaries are found in lower order centres. However, care should be taken in interpreting the correlation matrix as high correlation coefficient between two variables does not necessarily mean that the occurrence of one will lead to the occurrence of the other. From Table 1, we observed that Warri has the greatest value (381), followed by Effurun (240). These incidentally are centres with very high accessibility. At the extreme, centres with the least indices include Omadino (2), Ogidigbeu (3) and Oria (0). These are areas with low accessibility and low order centres. Table 2 gives the rank order of nodal accessibility by 2016 based on shortest road distance (See Appendix C-2). Figure 3 is a map of equal accessibility surfaces in Delta State.

Table 2: Rank order of Nodal accessibility using road distance of Delta State, 2016

Node No.	Nodal Title	Accessibility Index (km)	Rank order
29	Ughelli	2698.8	1
30	Otu-jeremi	2747.4	2
46	Okpara	3077.6	3
14	Ozoro	3184.8	4
28	Otor-udu	3202.1	5
39	Aladja (DSC)	3268	6
40	Ewu-Urhobo	3328.1	7
16	Patani	3334.1	8
6	Kwale	3351.2	9
32	Isiokolo	3356.5	10
45	Orogun	3465.5	11
36	Aviara	3491.4	12
43	Illah	3515.1	13
9	Obiaruku	3567.9	14
22	Uzere	3589	15
34	Oria	3665.2	16
31	Effurun	3779.8	17
44	Obior	3817.6	18
3	Owa-oyibu	3872.2	19
5	Ashaka	3882.3	20
48	Onicha-ugbo	3945	21
10	Abavo	4047.4	22
49	Owonta	4061.8	23
18	Warri	4091.2	24
15	Oleh	4092.1	25
24	Abraka	4095.7	26
4	Agbor	4113.9	27
47	Olomoro	4146.7	28
8	Asaba	4197	29
23	Kiagbodo	4232.5	30
2	Ogwashi-Uku	4278.9	31
33	Jeddo	4279	32
12	Bomadi	4328	33
35	Eku	4422.6	34
1	Issele-Uku	4433.6	35
20	Ogidigbeu	4467.6	36
11	Umuebu	4477.7	37
21	Omadino	4560.7	38
37	Kokori	4616	39

7	Ibusa	4634.7	40
26	Orerokpe	4709.1	41
51	Umutu	4720.6	42
13	Burutu	4808.5	43
42	Igbodo	5007.6	44
38	Adagbrasa	5015.5	45
19	Ogbe-Ijo	5182.4	46
50	Umunede	5233.1	47
27	Sapele	5310.1	48
25	Oghara	5550.1	49
17	Koko	5951.3	50

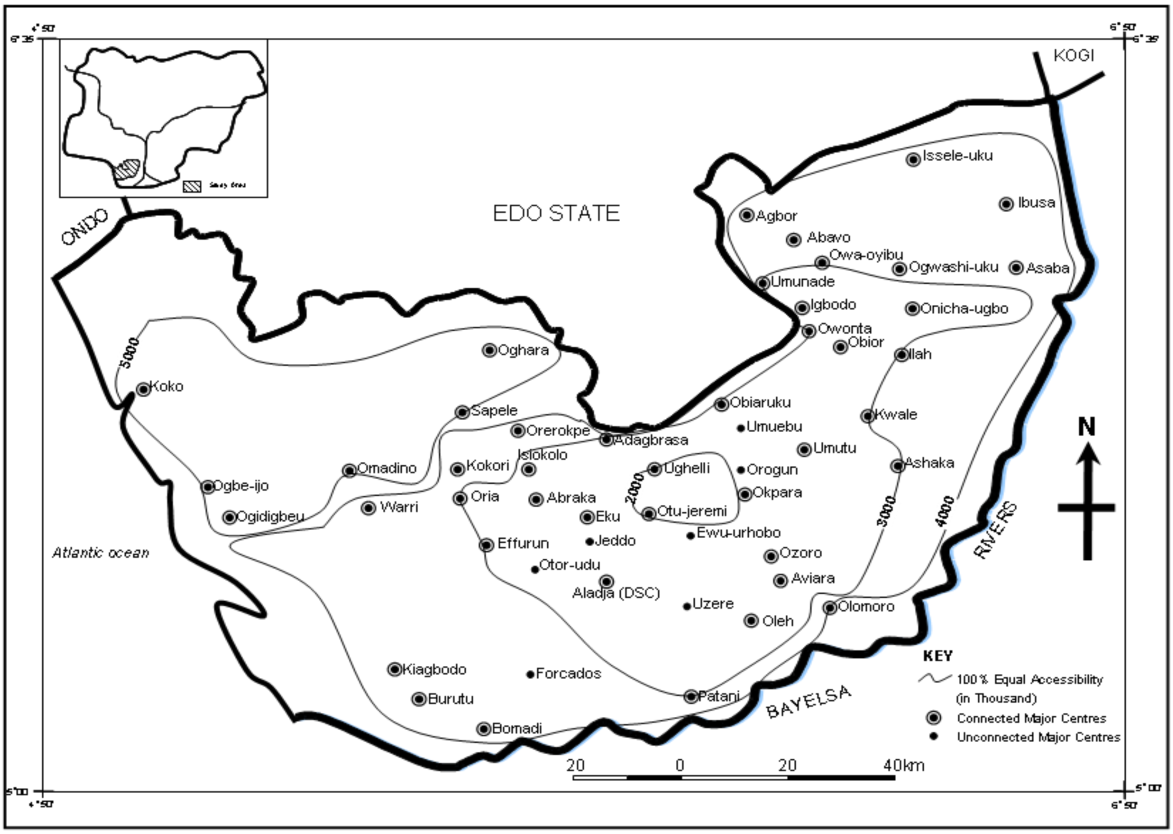

Fig. 3: Delta State showing areas of equal accessibility as at 2016

From the table, we observe that Ughelli (Ai = 2698.8) is the most accessible centre followed by Otu-jeremi (Ai = 2747.4) and Okpara (Ai = 3077.6) as the second and third most accessible centres in the network. Again we note that Koko, Oghara, Sapele and Umunede remained the least accessible centres with (Ai = 5951.3; 5550.1; 5310.1 and 5233.1) respectively.

However, it is also the purpose of this study to consider the pattern of accessibility to hospital facilities using other distance measures like travel cost and driving time, as shown in appendices D and E respectively. Appendix D gives the matrix of the 50 nodes with travel cost values between directly connected nodes. The travel cost includes both short and long distance faces along routes. Hence we have N200.00k as the cost of direct journey between Oleh and Uzere, but also we have N150:00k and N100:00k for the intermediate journeys from Oleh to Aviara giving a total of N250:00k if somebody were to consecutively stop at these intermediate centres before reaching Ozoro (See Fig. 4).

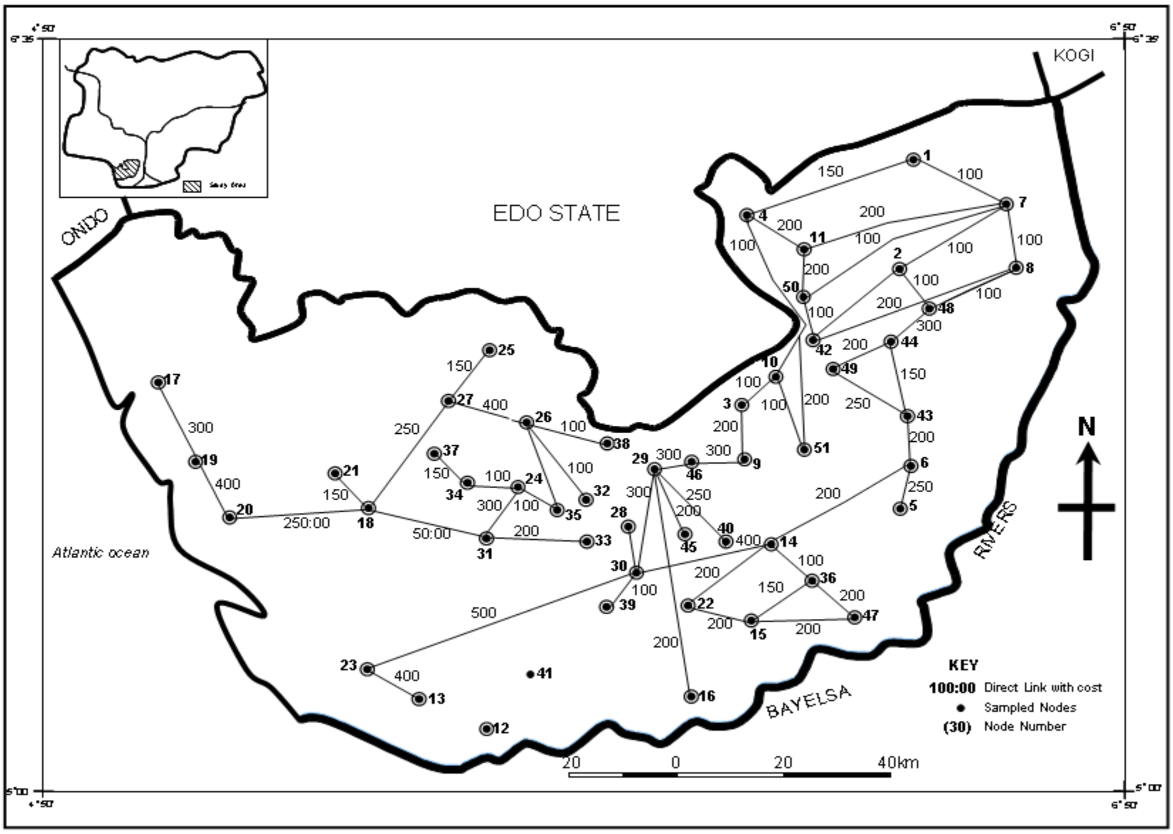

Fig. 4: Graph representation of road network in 2016 with Travel cost values

It was found that there is generally some relationship between link distance and travel cost. The correlation coefficient was calculated to be r = 0.86 (See Appendix F-1). Also the correlation between link distance and per kilometre cost was found to be (r = -0.45). This shows that the cost per kilometre is not directly related to distance. Perhaps other factors are more important (See Appendix F-2).

Appendix G shows the calculation of the correlation between road distance accessibility and functional index of hospital. The correlation coefficient (r) is given as r = 0.34 which shows that it is positive at 1% probability level of significance (appendix G-2). The positive correlation coefficient shows that the greater the accessibility index value (hence the less accessible the centre is), the higher the level of health facility occurrence. We would rather say that the coefficient indicates that the association between accessibility and functional index of health facility is strong. We also observe that a good number of centres with low accessibility have high function index and vice versa. Areas with the shortest road distance to all parts of the study area do not have more facilities. This is further discussed in analysis of residuals.

Meanwhile, we calculated the regression equation as shown in appendix G-3. It is of the form:

Log (F1H) = -0.1948 Log (RAI) + 0.444 …………………………. (1)

The equation (illustrated in figure 5) has a standard error of the estimate as 0.182 as shown in appendix G-4. The estimate at 95% confidence level also in appendix G-4 shows that there is a wide margin between the upper and lower limits.

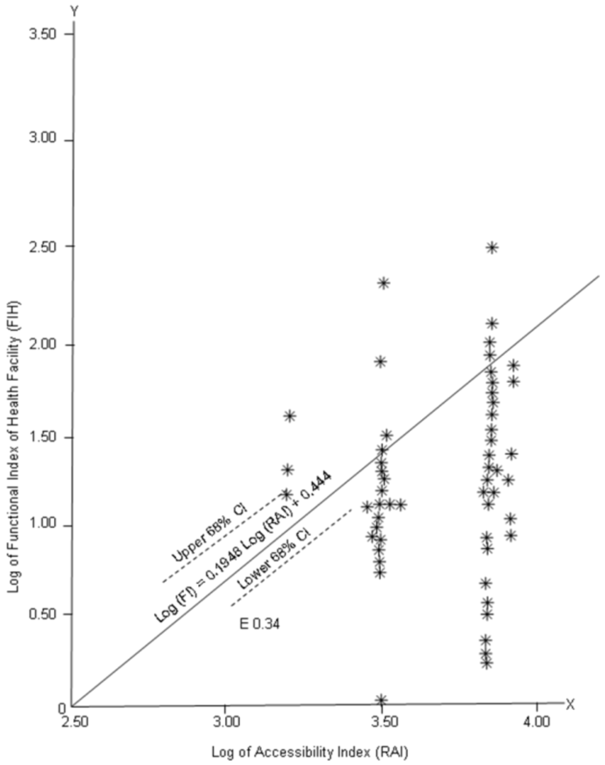

Fig. 5: Relationship between Functional Indices and Accessibility

From the map of figure 6 we observed that areas of positive residuals, which mean areas that tend to have more facilities than the assumed level of distance accessibility are widely distributed throughout Delta State.

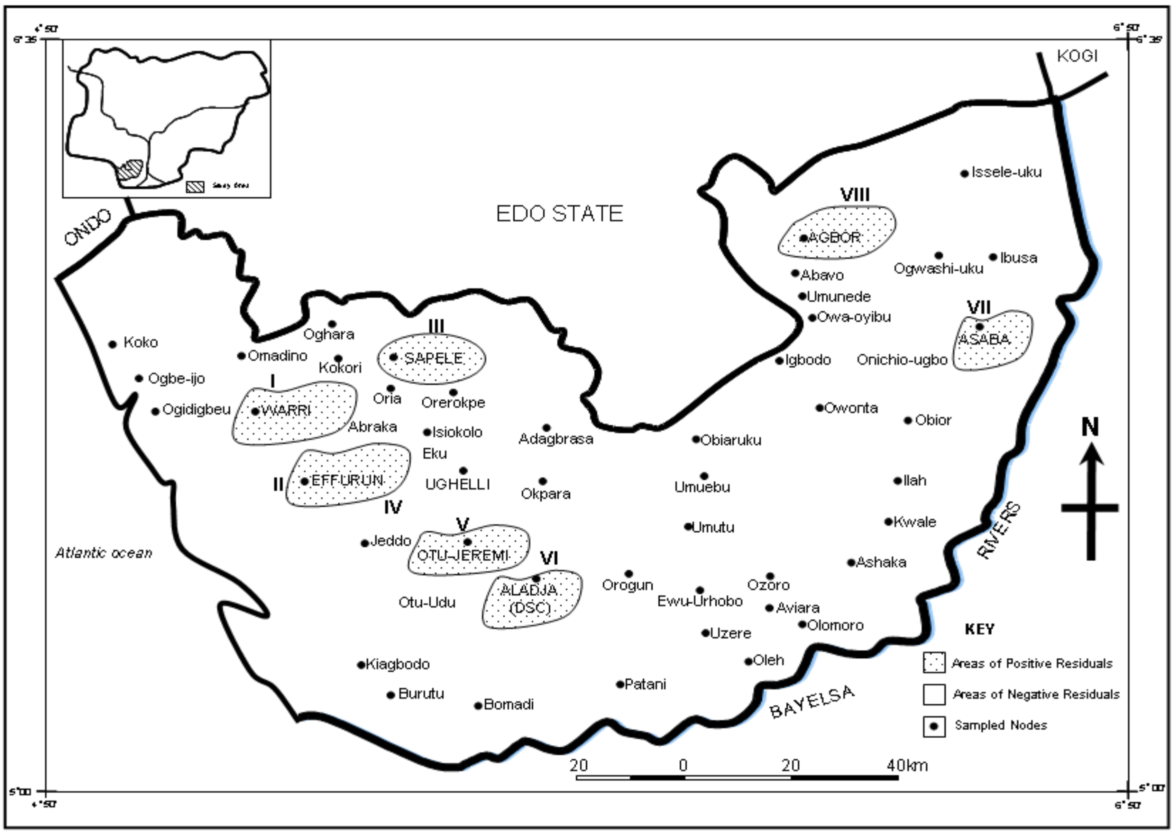

Fig. 6: Positive and Negative Residuals from the Regression of Functional Index on Accessibility

Rather it was observed that there are two areas of positive residuals. The first are those areas which have high accessibility indices and also corresponding high functional indices of health facilities. These are identified as I, II, VII and VIII or Warri areas, Effurun, Asaba and Agbor areas respectively. The second are those areas with low accessibility indices but high functional indices relative to the surrounding centres. These are marked by III, IV, V and VI. They are identified as Sapele, Ughelli, Otu-jeremi and Aladja (DSC) areas respectively.

Within the first group we observe that the network of roads is quite high and nodes are found at short distances from each other. Driving time within the centres in this group ranges from 15 minutes in Warri area to about 30 minutes in Agbor – Asaba axis. For these areas it maybe plausible to say that high level of accessibility is a contributory factor in attracting the concentration of facilities. Thus Agbor with the ninth highest accessibility index also possesses a good number of first or facilities – specialist hospital, general hospitals, large daily market and commercial banks. The same may be said to some degree of Orerokpe, Okpara, Owa-oyibu and Obiaruku. For these centres, it may be said that accessibility indices establishment of facilities and establishment of facilities demands improvement of accessibility.

In the second group we however notice that there is a wide variation in levels of accessibility associated with positive residuals. This ranges from Sapele (Ai = 5310.1) through Adagbrasa (Ai = 5015.5), Umutu (Ai = 4720.6), Okpara (Ai = 4146.6) to Abavo (Ai = 4047.4). Nonetheless we cannot say that road distance accessibility is the only important factor in the establishment of health facilities. This is especially true when we consider such centres in this area as Sapele, Okpara and Abavo. Uniquely Aladja (DSC) has a good number of functional index both in number and type of facilities. Yet Patani is at the verge of the periphery of the study area. So its importance has not much to do with its accessibility to other parts of Delta State.

In the analysis of areas of negative residuals which indicate areas having less than expected level of facility occurrence, we also notice a wide distribution of centres throughout Delta State. In fact, the areas of negative residuals are around the areas of positive residuals. We have centres that are peripherally located marked by high accessibility indices such as Ogidigbeu (Ai = 4467.6), Umutu (Ai = 4720.6) and Adagbrasa (Ai = 5015.5) which have low indices of health facility occurrence. This may look like neglect if we can consider distance accessibility alone. However, these centres have low population and this could account for the low level of health facility occurrence.

To assess the level of explanation provided by accessibility, we compute the coefficient of determination. This is simply given as

Coefficient of determination = I – r^2 …………………………. (2)

Where r = coefficient of correlation

This gives us about 0.34 or 1% implying that the road distance factor alone, explains only about 34% of the variation in the location of health facilities throughout Delta State. The policy implication of this study therefore, is that the strategy of constructing new links to improve accessibilitymay involve heavier financial investment. Thus a proper cost benefit analysis may be needed to determine the desirability of such investment.

IV. CONCLUSION

Healthcare is one of the most important facility and it helps to improve the quality of life and social welfare of modern society. As a conclusion, we touch upon the very issue of financing road projects. Some might ask: Where is the money all going to come from? What of the cost – benefit analysis? These are important questions and the specialist may have an answer. However, it is pertinent to point out that the social benefit of constructing a road that increase accessibility; saves time and reduce cost goes beyond the financial evaluation.

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