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Patterns of Nodal Accessibility on Influence of Cost and Time in Delta State, Nigeria (1976-2016)

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Abstract
The central aim of this study is to examine the patterns of nodal accessibility on influence of cost and time in Delta State, Nigeria. To be able to do this, the development of the transport network is first traced from 1976 to 2016. The data collected for the period between 1976 and 2016, were based on government documents. A classification of 50 sampled settlements, called centres, is first developed based on population size by means of graph theory. The complex network of roads is abstracted into set of nodes and edges. These nodes were subsequently weighted according to their number and functions. It is however, observed that there is some relationship between travel time and cost factors and distances; and high speed is observed to be concentrated within a given distance band (about 20.3km). Based on the findings, recommendations that would enhance equitable transport development in the study area include: constructing new roads that will increase accessibility, save time and reduce cost of other centres and relocation of some facilities.

Keywords: Influence; Time; Cost; Accessibility; Nodal.

Introduction
Accessibility is a loose term which is used to mean many things; hence, we need to specify the term as used in this study. Whereas various definitions of accessibility are put forward to connote, social, economic or legal nearness to needed services (Daly, 1975; Mitchell and Town, 1976; Rodrigue, 2004), that which emphasizes accessibility as inherent characteristics or advantage of a place with respect to over-coming some form of spatially operating source of friction or the relative degree of

ease with which a location can be reached from other locations is widely accepted by geographers and planners (Morill, 1970, Ingram, 1971, Li and Lu, 2005).

Spatial accessibility has become a prerequisite to the integration of the urban centre and its circumference (Cao and Yan, 2006). The spatial evolution of metropolitan area and the development of its transport network are in interactive process (Wang and Jim, 2005). A well developed transport network has become the basic condition and essential prerequisite 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 analyzing and evaluating the spatial structure of that by studying its transport network and spatial accessibility between the urban centre and its circumference (Hodge, 2009).

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).

Transportation infrastructure is often measured as a key to promoting growth and development. The argument relies on the simple logic that one first needs to have values to markets and ideas before one can benefit from them. This belief is supported by the observation that the historical construction of infrastructure such as railroads coincided with periods of rapid economic growth in Western Europe, Japan and the United States. Today, it is an indisputable fact that richer countries have dramatically better transportation infrastructure than poorer ones (Aoyama et al, 2009; Munshi and Mark, 2009).

Closely related to the problem of defining accessibility is the problem of measuring it faced with the problem of providing a theoretical basis for measuring spatial nearness. Bunge (1962) merely related an observation made by earlier workers when he said that in a uniform surface, the shortest distance between two points is a straight line. In a real world, however, surface is neither uniform nor is the "shortest" distance between two points necessarily a straight line. Yet for want of readily available alternative, direct distance or road distance is often employed as a measure of relative accessibility (Keebler et al, 1982; Okarazu, 1983; Mclafferty, 1983; Atubi & Onokala, 2004a and Chen & Cheng, 2007).

Such alternative as travel time as used by Chisholm, (1962) and Ojo (1973), Ajiboye & Afolayan, 2009), in a study of agricultural societies, Burton et al (1980) and Atubi, (2008d) in urban journey to work patterns and Mirchandoni and Odoni (1979) in a model of new facilities is not without difficulties in measurement. For example, Chapman (1950) had earlier showed that a significant difference does exist between actual time and time as perceived by travellers.

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). However, Onokerhoraye (1976) and Okafor (1982) sought to identify the major factors that influence distribution of post primary schools in Ilorin and Ibadan respectively. They attributed the larger catchments areas to urban schools to travel distance to school and also to population of urban centres. Bardi (1982) and Atubi & Ali, (2006) also investigated the relationship between growth of road network and accessibility of urban centres in Bendel State and Warri respectively, while Abumere (1982) tried to establish the nodal structure of Bendel State. They arrived at the conclusion that accessibility declined from the state capital of Benin-City to the peripheries of the state. Bardi (1982) in addition noted that changes in road network connectivity led to the decline in accessibility of some towns in the state. Other studies from the Western part of Nigeria have shown concern for single facility location problems such as Okafor's (1976, 1980) study of efficient location and influence of general hospitals in Afenmai District of Bendel state, Oherein's (1985) study of access to postal services in Owan Local Government Area also of Bendel State, and Agwu's (1987) study of the relative accessibility of centres to the road network in Imo state and Mohammed and Dahunsi (2003) study of the evaluation of road transport accessibility to local government headquarters in Edo State.

Whereas Okafor noted that the population and transport cost to the hospitals were the two major constraints in efficient location of hospitals, Oherein observed that not only did accessibility decline from the major towns located at the centre of those of the peripheries but also, there was decline in patronage to individual postal services with increasing distance from the centre. As has been noted, provision of services form an important sector of the economy in the state for which transport ought to be related. Also Agwu observed that population of centres was found to be a more significant factor in the distribution of facilities. From the foregoing discussions of past studies in Nigeria we 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).

Road network planning (or design) problems consist of determining the best investment decisions to be made with regard to the improvement of a road network. The degradation of the quality of service provided by the network that may occur in case of fluctuations in travel demand or disruptions in infrastructure supply is typically not taken into account in models designed to represent those problems. Yet this type of occurrences can have a severe impact on both the welfare of individual drivers and the performance of economic systems as a whole (Bruno et al, 2014).

A considerable research effort has been devoted to road network planning models over the last forty years. The vast majority of these efforts was 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) Suwansirikul 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).

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).

Atubi and Ali (2006), examined the role of political policies in influencing transportation facilities in Warri metropolis, Delta State. They maintained that politics had more than desired influence on the city network and this is irrational to objective planning of transport network in such a large city. They also said that until the city was given a new dimension such as planning and reversing some existing policies, the traffic problems in metropolitan Warri would continue to be inexistence to be prevalent.

As a complement of creating more physical capacity through major investment in urban transport infrastructure, many cities have attempted to make more effective use of existing road space by traffic engineering techniques. Some have attempted to translate these techniques into effective traffic management schemes to reduce demand and/or give priority to moving people rather than vehicles – by providing facilities for high occupancy vehicles such as buses, (Midgley, 1995 and Chengliang Liu and Ruilin, 2012).

Study Area

Delta State is bounded in the north by Edo State, the east by Anambra State, south-east by Bayelsa State, and on the southern flank by the Bight of Benin which covers about 160 kilometres of the state's coastline (see Fig. 1). Delta State is generally low-lying without remarkable hills, and covers a landmass of about 18,050 km^2 of which more than 60% is land. The state has a wide coastal belt inter-laced with rivulets and steams, which form part of the Niger Delta (The force of diversity, 2013). Presently, Delta State comprises 25 local government areas. The capital of Delta State is Asaba, and it is located at the northern end of the state with an estimated land area of 762 km^2.

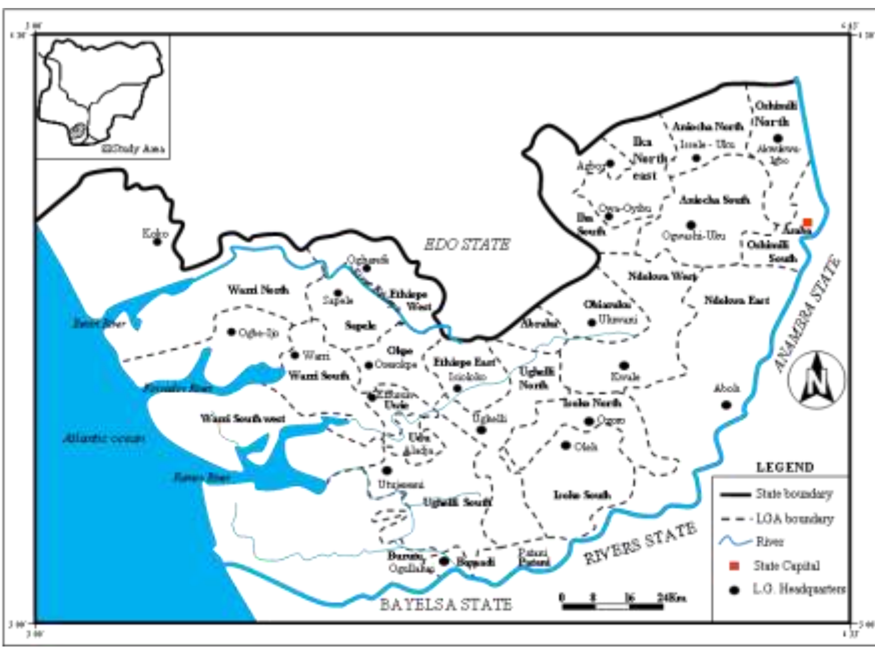

Fig. 1: Map of Delta State showing Study Area

According to the 2006 National Population Census, Delta State had a population of 4,112,445 people. 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 2014 was estimated at 5,315,816 with an annual growth rate of 3.3%. Table 1 shows population figures estimated for 2012 – 2016.

Table 1: Estimated population of Delta State by Local Government Area (2012-2016)

		Estimated Population 2012-2016				
S/N	**LGA**	**2012**	**2013**	**2014**	**2015**	**2016**
1	Aniocha North	127231	131430	135767	140248	144876
2	Aniocha South	170844	176482	182306	188322	194536
3	IkaNorth-East	223156	230521	238128	245986	254104
4	Ika South	197563	204083	210818	217775	224961
5	Ndokwa East	125360	129497	133770	138185	142745
6	Ndokwa West	181441	187428	193613	200002	206603
7	Oshimili North	140117	144741	149518	154452	159549
8	Oshimili South	181418	187404	193589	199977	206576
9	Ukwani	146282	151110	156096	161248	166569
10	Bomadi	105279	108753	112342	116049	119879
11	Burutu	254752	263159	271843	280814	290081
12	Isoko North	175159	180939	186910	193078	199449
13	Isoko South	276686	285817	295249	304992	315057
14	Patani	82271	84986	87791	90688	93681
15	Warn North	166829	172335	178022	183896	189965
16	Warn South	368673	380840	393407	406390	419801
17	Warn South-West	141776	146454	151287	156280	161437
18	Ethiope East	243977	252028	260345	268936	277811
19	Ethiope West	247379	255542	263975	272686	281685
20	Okpe	158238	163459	168854	174426	180182
21	Sapele	208856	215749	222868	230223	237820
22	Udu	174194	179942	185880	192014	198351
23	Ughelli North	390072	402944	416242	429978	444167
24	Ughelli South	259510	268074	276920	286059	295499
25	Uvwie	232653	240331	248262	256455	264918
	Total	**4981728**	**5146061**	**5315816**	**5491174**	**5672318**

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. For a prior understanding of the present system and its influence in nodal accessibility the evolution of the network from 1976 (taken as the base year) to 2016 was considered.

The structural characteristics and accessibility of major centres to the road network was considered at four points in time – 1986, 1996, 2006 and 2016. The study intends to analyse the road network for a period of four decades (1976-2016) at ten-year intervals.

In developing the research design, areas that are accessible to the road networks and with population of 10,000 and above at each period where taken as activity centres. Using 1976 as the base year any centre within the study area with a population of 10,000 and which is connected by the road network was regarded as a node. Population of 10,000 was chosen as cut-off point to enable a substantial number of centres, especially those at the end of routes to appear as nodes as the network grows. 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 consider changes in accessibility of centres three sets of maps that closely reflects the conditions of the road network in the four time periods were collected from ministry of lands, survey and urban development, Asaba. These are: map of Asaba and environs – street guide map 1:25,000 published in 1996 and Delta State map 1:300,000, published in 2008. These maps closely reflect the nature of roads in Delta State from 1991 when the state was created.

However, the state of roads in 2015 was updated from the 2008 map in the Ministry of Lands, Survey and Urban Development, Asaba and from various sampled centres. From these surveys data on travel time and cost were collected both by personal observation and oral interviews.

Measurement of distance, time or cost is assumed to be between centres. The road distance between two major centres was determined by using thread or string to measure the distance on the map and by using appropriate scale given to work out the actual distance. The main mode of transport upon which data were based is the minibus, tricycle (keke) and motorcycle (okada) which can be seen in every corner of Delta State. They were chosen for their relative versatility as they are capable of penetrating remote areas.

The time data represent average journey time by the 504 model of Peugeot and mini bus or motorcycle. This, it is believed reflects the nature of the road surface. On the other hand travel cost data are based on authorized fares by the national union of road transport workers (NURTW) which is the national trade union body that coordinates road transport fares throughout the country. Although some other transport unions and individuals charge different rates, the NURTW fares were adopted because of uniformity and consistency.

The relative accessibility of centres to the road network in Delta State was analysed using the technique of graph theory. It is used to handle properties of transportation networks in order to bring out their characteristics and structure. Other major techniques of analysis used include the homogenization of data, totals, means, percentages and maps. These were used to deduce patterns.

Discussion of Results/Findings

Table 2: Indices of Connectivity (1976-2016)

Symbol	1986	1996	2006	2016
Number of edge (e)	26	31	44	50
Number of vertices (v)	22	26	36	56
Cyclomatic number (μ)	5	6	9	6
Beta index (β)	1.18	1.19	1.22	1.12
Gamma index (γ)	43.33	43.06	43.14	39.0
Alpha index (α)	14.71	14.28	14.52	15.71
Connectivity index (c)	11.26	9.54	6.98	6.41

Source: Fieldwork, (2016)

We however observe from table 2 that:

1. the cyclomatic number increased from 5 in 1986 to 9 in 2006 and decreased to 6 in 2016 which implies that the number of circuits increased up to a certain period and later decreased between the time periods under study;

2. the β-index which indicates the ratio between the number of links and connected nodes also increased in value between 1976 and 2006 but after 2006 it decreased and remained so till 2016.
3. both the gamma and alpha indices indicate increasing complexity of network with time. Generally therefore, we can say that there appears to be an increase in the degree to which the nodes become connected; and
4. the connectivity index (c) of the road network in Delta Stat is 9.54% of the maximum possible connectivity.

Although the indices of connectivity indicate decreasing complexity of network between 1976 and 2016, the indices of nodal accessibility which explain the accessibility of one node to all others in the network indicate the changing fortunes of some centres (see Figs. 2, 3, 4, 5 and 6).

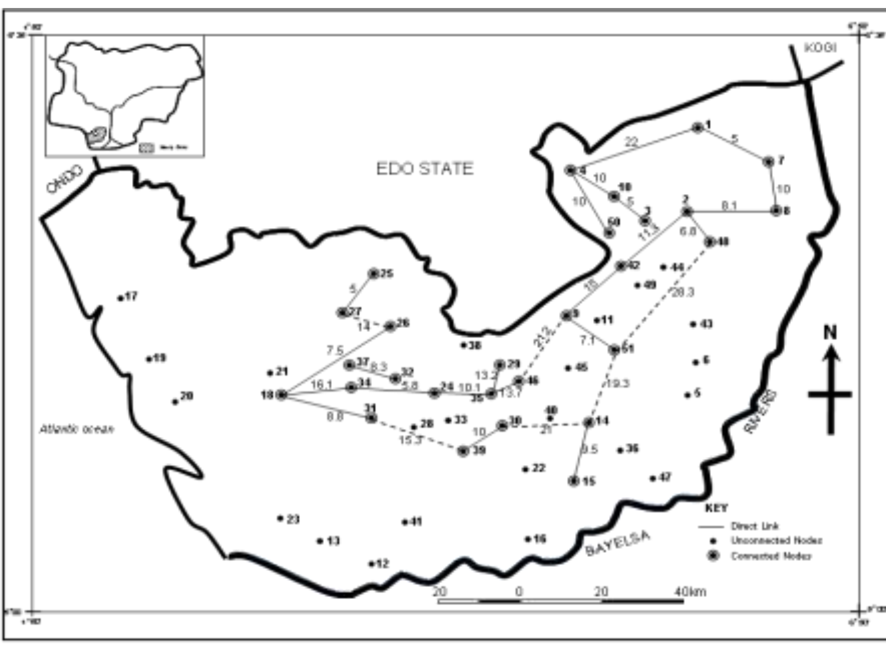

Fig. 2: Graph Representation of 1976-1986 Road Network with Road Distance Values

Source: *Fieldwork (2016)*

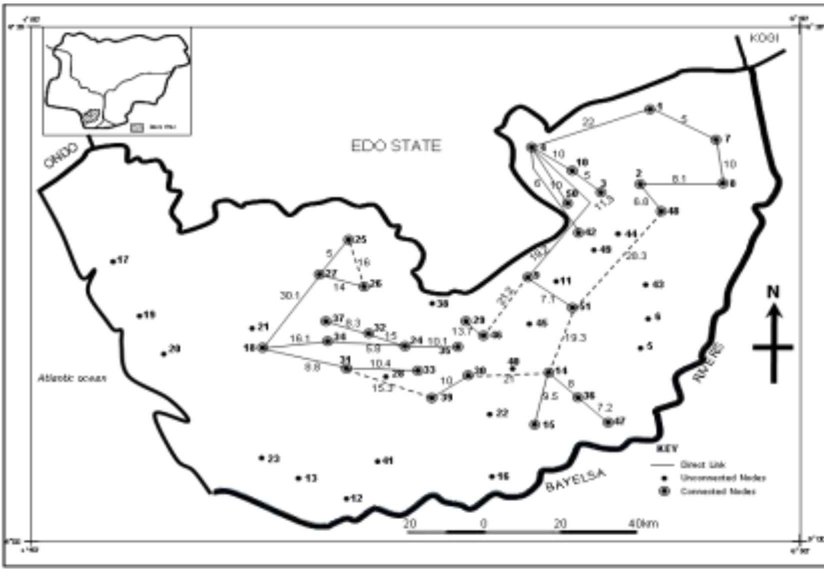

Fig. 3: Graph Representation of 1986-1996 Road Network with Road Distance Values
Source: *Fieldwork (2016)*

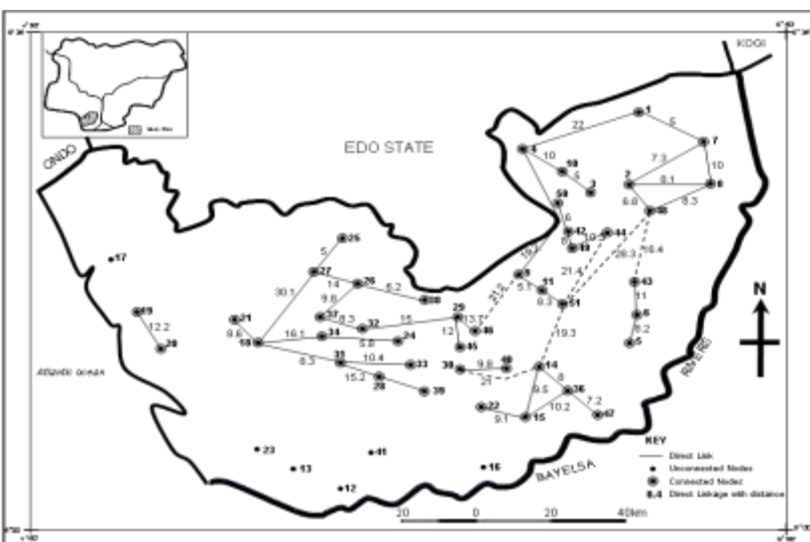

Fig. 4: Graph Representation of 1996-2006 Road Network with Road Distance Values

Source: *Fieldwork (2016)*

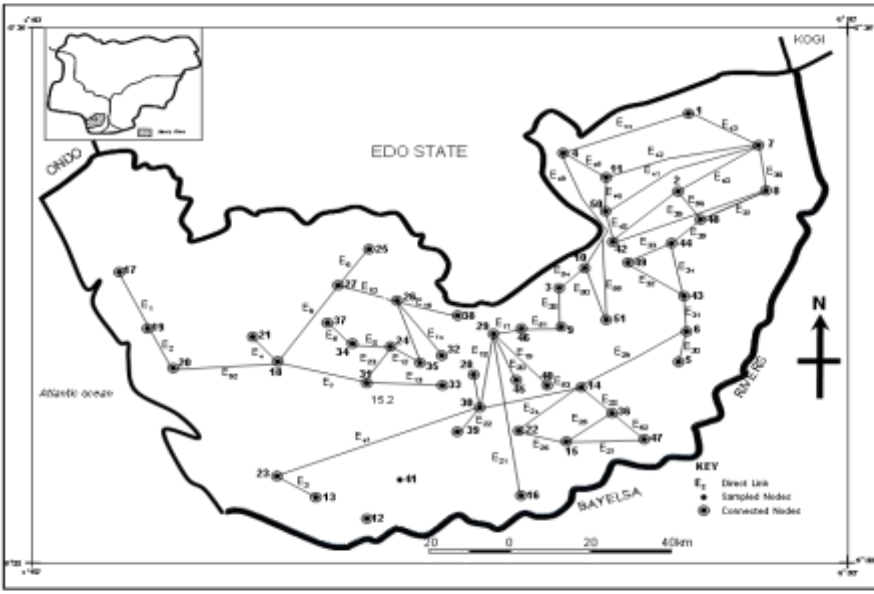

Fig. 5: Graph Representation of 2006-2016 Road Network
Source: *Fieldwork (2016)*

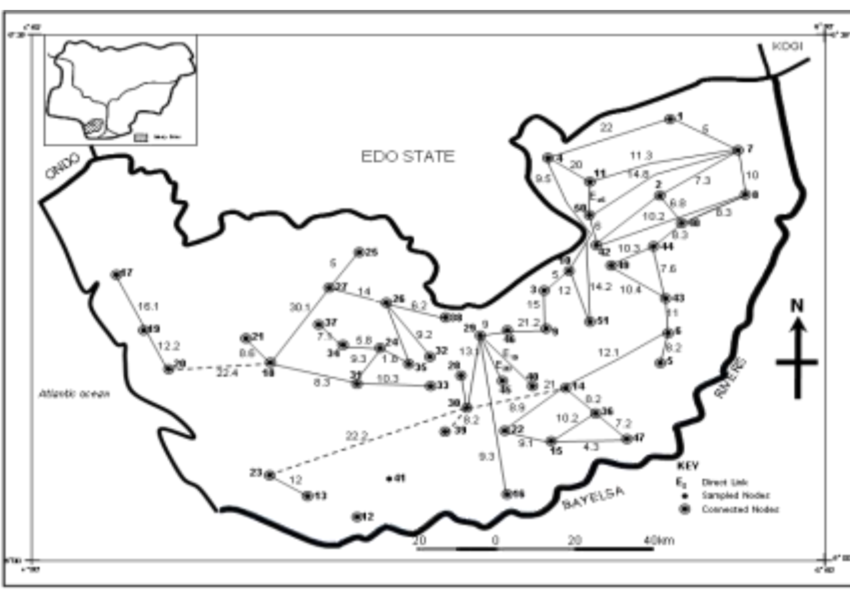

Fig. 6: Graph Representation of Road Network: 2016 with Road Distance Values
Source: *Fieldwork (2016)*

In Table 3, the centres are ranked according to their level of accessibility for 1986. The higher the index, the less accessible the node and vice versa.

Table 3: Rank order of Nodal accessibility using road distance of Delta State, 1986

Node No.	Nodal Title	Accessibility Index (km)	Rank order
9	Obiaruku	1346.6	1
51	Umutu	1389.2	2
42	Igbodo	1426.6	3
2	Ugwashi-uku	1452.5	4
14	Ozoro	1519.2	5
35	Eku	1528.8	6
48	Onicha-ugbo	1557.6	7
34	Oria	1614.9	8
8	Asaba	1626	9
24	Abraka	1654.3	10
30	Otu-jeremi	1667.6	11
46	Okpara	1695.8	12
1	Issele-uku	1727	13
18	Warri	1730.7	14
39	Aladja (DSC)	1741.6	15
29	Ughelli	1752.4	16
15	Oleh	1771.3	17
7	Ibusa	1793.1	18
31	Effurun	1821	19
26	Orerokpe	1895.4	20
4	Agbor	1960.3	21
27	Sapele	2191.7	22
25	Oghara	2239.4	23
10	Abavo	2460.9	24
50	Umunede	2488.1	25
3	Owa-oyibu	2552.1	26

It is interesting to note that in terms of overall road distance, the most accessible centres in 1986 were Obiaruku (Ai = 1346.6), Umutu (Ai = 1389.2) and Igbodo (Ai = 1426.6) while the least accessible were Abavo (Ai = 2460.9), Umunede (Ai = 2488.1) and Owa – Oyibu (Ai = 2552.1). Surprisingly Warri, the most populous centre scored (Ai = 1730.7), thereby taking the 14th position in the rank order.

Figure 7 shows lines of equal accessibility as at 1986 from the map it is observed that the 1600 line encloses an area with the highest level of accessibility comprising of Onicha-Ugbo, Eku, Ozori, Obiaruku, Umutu, Ogwashi-uku and Igbodo. These are areas that could be reached easily from any part of Delta State as at that time.

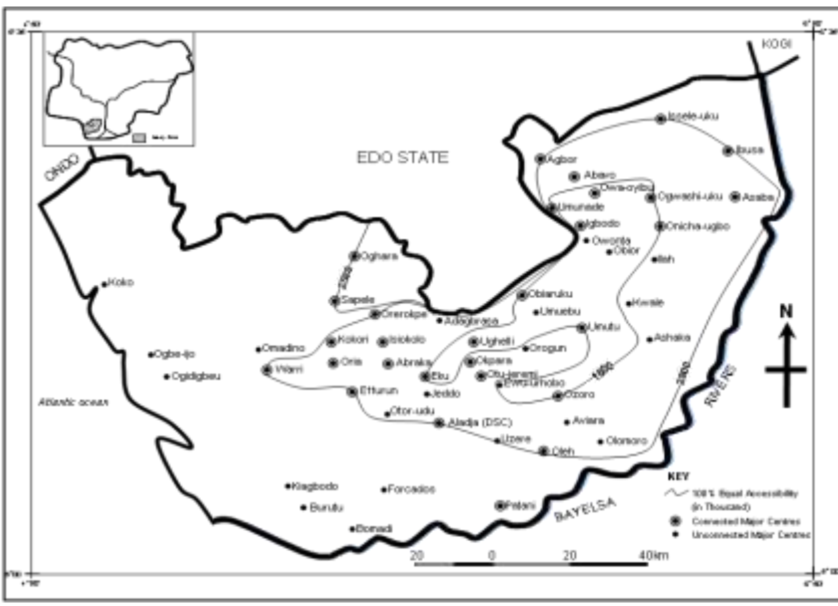

Fig. 7: Delta State showing areas of Equal Accessibility as at 1986 (1976-1986)
Source: *Fieldwork, (2016)*

Immediately after the central area, there is a group of relatively accessible centres consisting of Asaba, Oria, Abraka, Otu-Jeremi, Okpara, Issele-Uku, Warri Aladja (DSC), Ughelli, Oleh, Effurun, Ibusa, Orerokpe and Agbor. There are, however, areas such as Aviara, Olomoro, Kwale, Ilah, and Uzere which are in this group that had not been connected to the road network at that time. These could be considered as potential centres of high accessibility.

From the 2500 line, accessibility declines rapidly outwards indicating that centres in these areas are relatively less accessible to the network as at 1986. They constitute the peripheral centres of Delta State, while some centres are not connected at all.

Table 4 gives the rank order of nodal accessibility by 1996 based on shortest road distance. Fig. 8 is a map of equal accessibility surfaces in Delta State up to 1996 based on table 4.

From the table we observe that Ozoro (Ai = 1668.7) had become the most accessible centre, while Umutu (Ai = 1726.6) and Otu-jeremi (Ai = 1753.7) had become the second and third most accessible centres in the network. Again we noted that Isiokolo, Oghara, Kokori and Oreropke remained the least accessible with (Ai = 2932.7, 30.98.5 and 3193.1) respectively.

Table 4: Rank order of Nodal accessibility using road distance of Delta State, 1996

Node No.	Nodal Title	Accessibility Index (km)	Rank order
14	Ozoro	1668.7	1
51	Umutu	1726.6	2
30	Otu-jeremi	1753.7	3
9	Obiaruku	1778.7	4
39	Aladja (DSC)	1840.7	5
36	Aviara	1894.6	6
15	Oleh	1953.8	7
31	Effurun	1956.5	8
4	Agbor	2079.8	9
47	Olomoro	2093.2	10
18	Warri	2125.6	11
42	Igbodo	2253.8	12
33	Jeddo	2268.9	13
48	Onicha-Ugbo	2287.6	14
50	Umunede	3349.7	15
10	Abavo	2356.9	16
46	Okpara	2377.5	17
2	Ogwashi-Uku	2405.7	18

Node No.	Nodal Title	Accessibility Index (km)	Rank order
34	Oria	2415.8	19
8	Asaba	2424.2	20
3	Owa-Oyibu	2494.7	21
1	Issele-uku	2541.7	22
24	Abraka	2549.2	23
7	Ibusa	2560.1	24
29	Ughelli	2774.5	25
27	Sapele	2820.2	26
35	Eku	2842.1	27
32	Isiokolo	2932.7	28
25	Oghara	3098.5	29
37	Kokori	3174.8	30
26	Orerokpe	3193.1	31

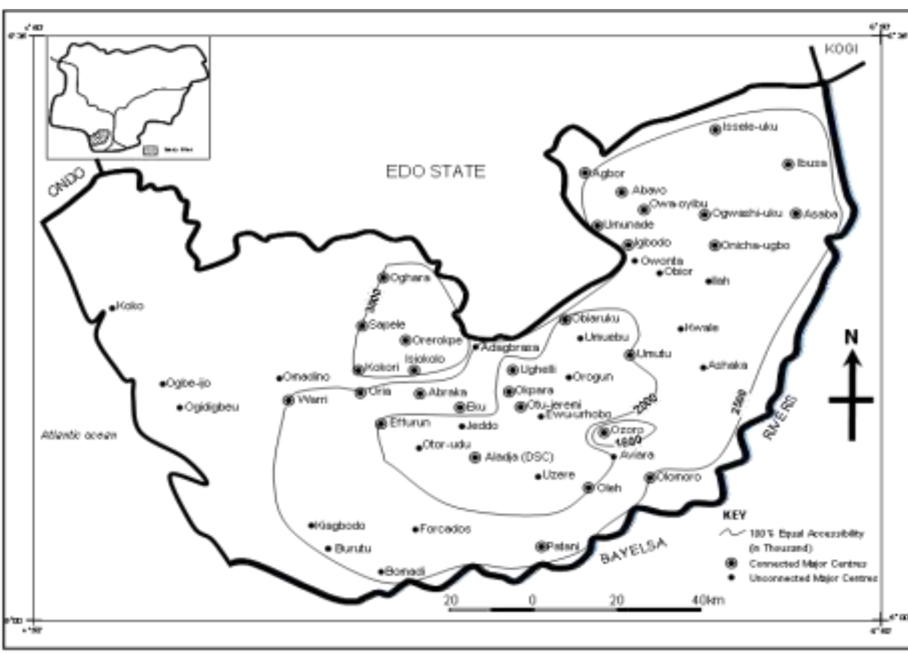

FIG. 8: Delta State showing areas of Equal Accessibility as at 1996 (1986-1996)
Source: *Fieldwork, (2016)*

Figure 8 shows lines of equal accessibility as at 1996 from the map it is observed that the 1600 line encloses an area with the highest level of accessibility which is Ozoro. This is an area that could be reached easily from any part of Delta State as at that time.

Figure 8 also illustrate the existence of a central area of high accessibility delimited by the 2000 line. In this area, there are two centres of greatest accessibility enclosed by the 1600 line found around Umutu and Otu-jeremi axis. The emergence of these two centres reflects the addition of new lines along these routes namely Aviara – Olomoro, Isiokolo – Kokori and Jeddo – Effurun.

Table 5 gives the rank order of nodal accessibility by 2006 based on shortest road distance. Figure 9 is a map of equal accessibility surface in Delta State up to 2006 based on table 5. From the table we observed that Okpara (Ai = 2989.5) became the most accessible centre which differs from the nodal accessibility by 1996, while Umutu (Ai = 2997.8) remained the second most accessible centre in the network which corresponds with the nodal accessibility by 1996. We also note that Jeddo, Otor-Udu and Aladja (DSC) are the least accessible centres with (Ai = 5438.4, 5600.0 and 6024.2) respectively.

From the analysis we observe that there was meaningful development that took place in Delta State between 1996 and 2006. The pattern of nodal accessibility shown in Fig. 9 emphasises the existence of a central area of high accessibility centres. From the map we observe that 2000 equal accessibility line encloses Okpara and Umutu. The line clearly excludes an area along Ewu/Urhobo – Omadino – Ogbe-ijo – Ogidigbeu – Ashaka axis which has low accessibility resulting from being poorly connected to the network. The emergence of Okpara, Umutu and Umuebu as the most accessible centres reflects the addition of new lines along these routes namely Omadino – Ogbe – iju – Ogidigbeu – Ewu/Urhobo – Adagbrasa – Owonta – Umuebu – Obior and Ashaka – Otor-udu – Aladja (DSC). Their entry into the network has the effect of increasing the accessibility value for all the nodes.

Table 5: Rank order of Nodal accessibility using road distance of Delta State, 2006

Node No.	Nodal Title	Accessibility Index (km)	Rank order
46	Okpara	2989.5	1
51	Umutu	2997.8	2
11	Umunede	3026	3
9	Obiaruku	3060	4
29	Ughelli	3111.1	5
4	Agbor	3401.3	6
37	Kokori	3497.9	7
26	Orerokpe	3584.3	8
48	Onicha-Ugbo	3607.9	9
45	Orogun	3615.1	10
14	Ozoro	3623.8	11
44	Obior	3628.4	12
8	Asaba	3829.2	13
36	Aviara	3838.3	14
38	Adagbrasa	3838.7	15
27	Sapele	3854.5	16
7	Ibusa	3893.3	17
15	Oleh	3898.1	18
2	Ogwashi-Uku	3898.7	19
1	Issele-uku	4009.5	20
25	Oghara	4060.9	21
47	Olomoro	4140.7	22
43	Illah	4153.6	23
49	Owonta	4156.5	24
6	Kwale	4209.6	25
10	Abavo	4237.2	26
22	Uzere	4280.3	27
32	Isiokolo	4291.9	28
30	Otu-jeremi	4325	29
50	Umunede	4454.7	30
3	Owa-oyibu	4459.6	31
19	Ogbe-ijo	4531.1	32
20	Ogidigbeu	4657.7	33
18	Warri	4673.5	34

Node No.	Nodal Title	Accessibility Index (km)	Rank order
42	Igbodo	4685.7	35
31	Effurun	4729	36
40	Ewu-Urhobo	4783.9	37
5	Ashaka	4902.8	38
21	Omadino	5034.7	39
34	Oria	5309.2	40
24	Abraka	5431.1	41
33	Jeddo	5438.4	42
28	Otor-Udu	5600	43
39	Aladja (DSC)	6024.2	44

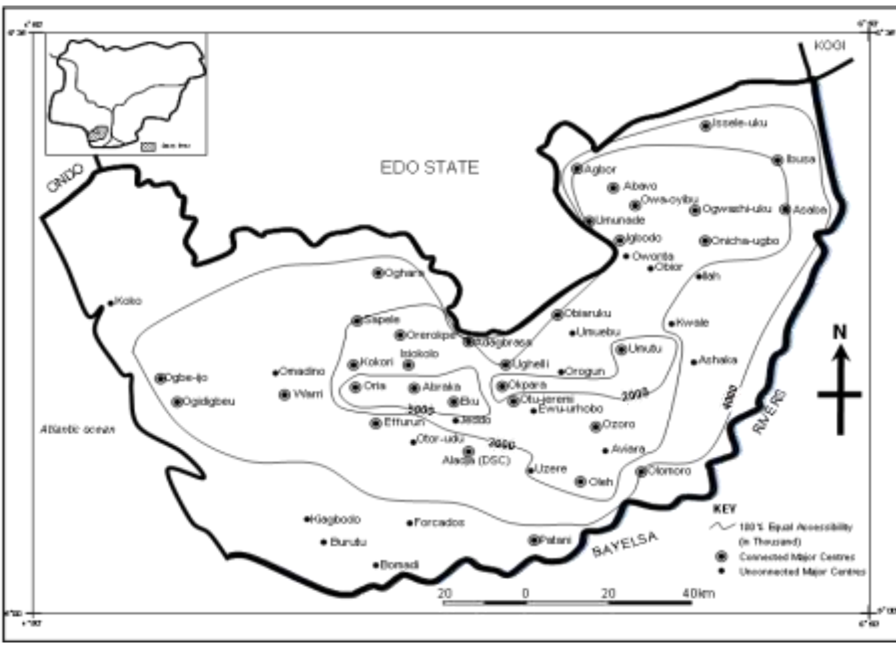

Fig. 9: Delta State showing areas of Equal Accessibility as at 2006 (1996-2006)
Source: *Fieldwork, (2016)*

Table 6 gives the rank order of nodal accessibility by 2016 based on shortest road distance. Figure 10 is a map of equal accessibility surfaces in Delta State up to 2016 based on Table 6

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.

From the analysis we observe that there was no meaningful development that took place in Delta State. The pattern of nodal accessibility shown in figure 10 emphases the existence of a central area of highly accessible centres. From the map, we observe that 2000 equal accessibility line enclose Ughelli and Otu-jeremi. The line clearly excludes an area along Adagbrasa – Sapele – Oghara axis which has low accessibility resulting from being poorly connected to the network. The existence of a central area which has remained consistently very accessible throughout the period is best illustrated by Figures 11 and 12 which are superimposed maps of the four periods.

Table 6: 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

Node No.	Nodal Title	Accessibility Index (km)	Rank order
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

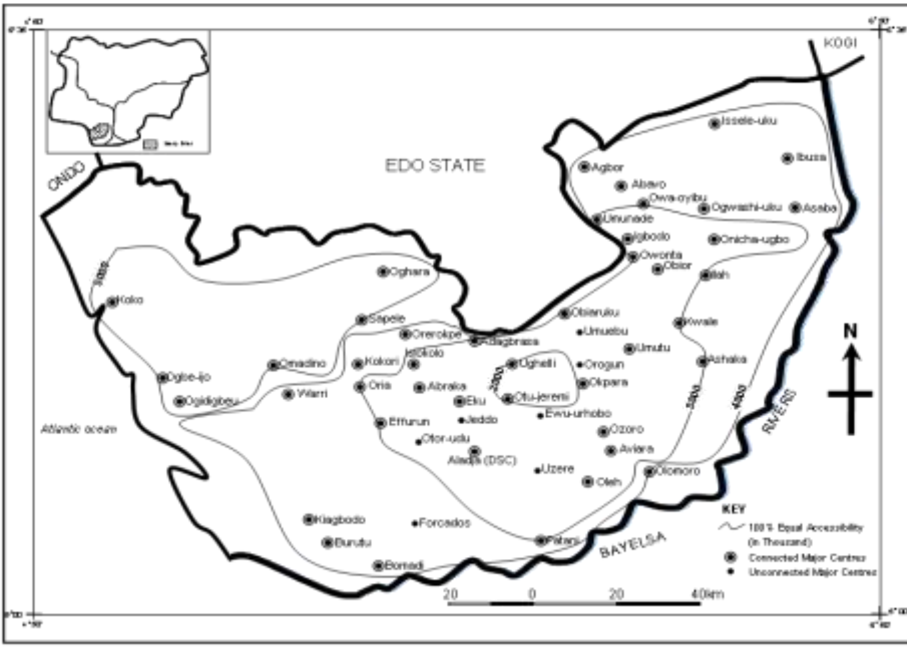

Fig. 10: Delta State showing areas of Equal Accessibility as at 2016 (2006-2016)
Source: *Fieldwork, (2016)*

The Ughelli – Okpara – Otu-jeremi – Obiaruku axis seems to have been enjoying high levels of accessibility throughout the period. The more nodes are connected the greater the accessibility value for individual nodes. However, the entire network accessibility expands with increasing number of nodes brought into the network.

Another observation is that there are some nodes (Kiagbodo, Ogidigbeu, Patani and Kokori) that were not connected in earlier dates but they acquired quite high accessibility as soon as they were connected. On the other hand those at the peripheries remained poorly accessible throughout the period.

It is observed further that there are some nodes which declined in accessibility as more links were added. Thus Okpara Umutu, Umuebu, Obiaruku, Orerokpe and Ozoro among others, declined in accessibility. This observation that some nodes declined in accessibility with time tends to negate our hypothesis that there is some significant relationship between areas which had initial high accessibility and areas which had high levels of accessibility with increasing complexity of network.

A comparison of the four maps of equal accessibility enables us to delimit the study into four regions of accessibility shown in figure 13. Thus we have a central core of high accessibility centres. This is delimited by the 2016 accessibility index of less than 3400. Within this area as can be observed are the best connected nodes.

Between 3400 and 3900 index lines are nodes of intermediate accessibility. Here some of the nodes have undergone changes in accessibility as discussed in the earlier paragraph. Some have recently been connected hence their accessibility to the network improved rapidly. Such as Aviara, Obior, Ashaka and Patani road.

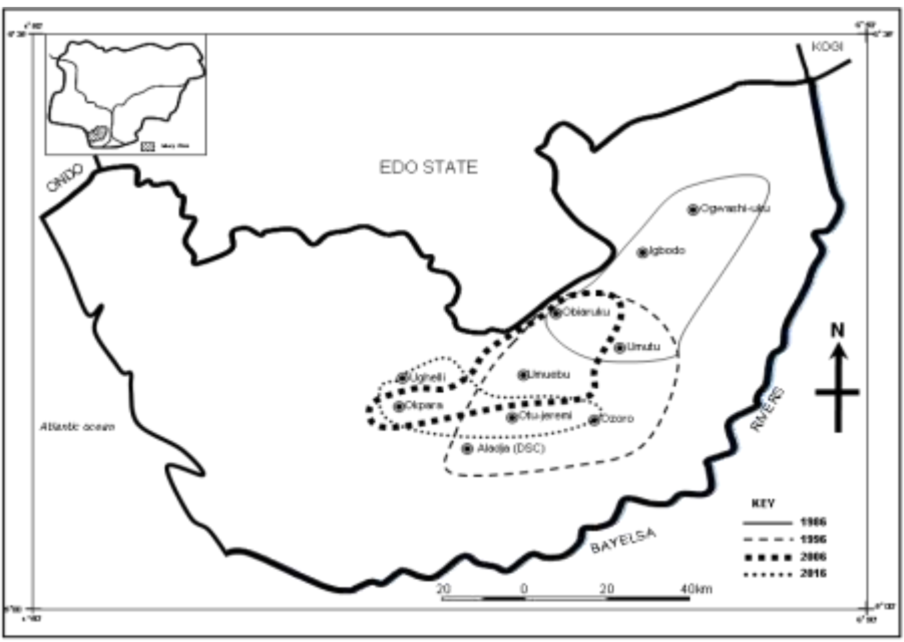

Fig. 11: Superimposed Map showing inner Centre of Highly Accessible Area (1976-2016)

Source: *Fieldwork, (2016)*

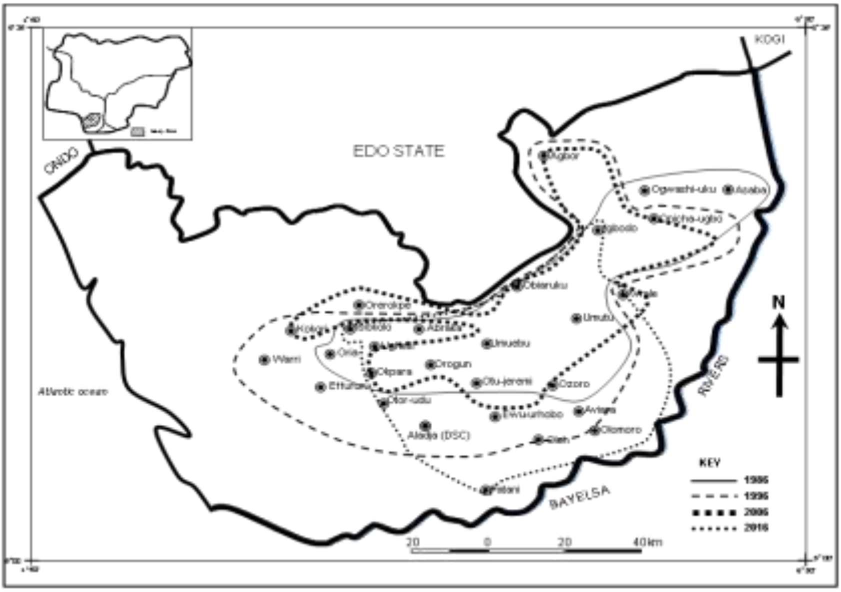

Fig. 12: Second most Accessible Area between 1976-2016
Source: *Fieldwork, (2016)*

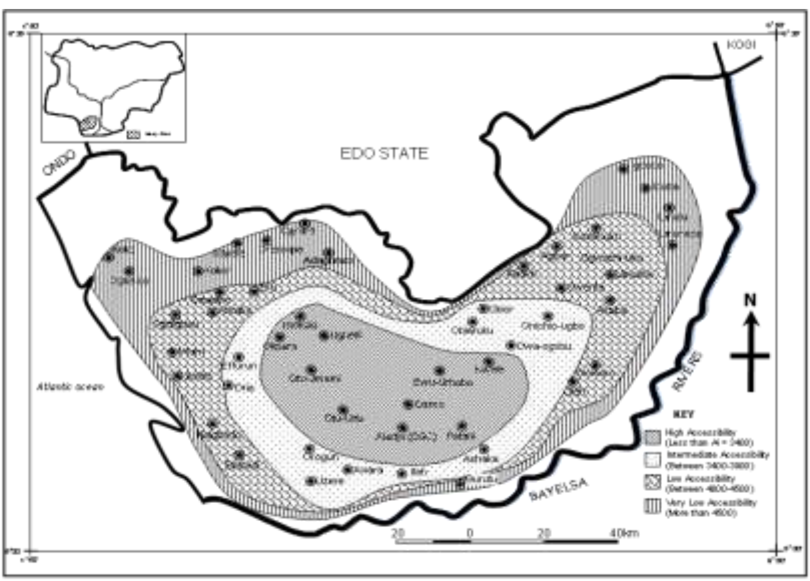

Fig. 13: Division of Delta State into Regions of Accessibility Based on Distance
Source: *Fieldwork, (2016)*

Between the 4000 and 4500 index lines are nodes of low accessibility. Here again, some of the nodes have undergone changes in accessibility. Some have recently been connected hence their accessibility to the network improved rapidly and examples include Kiagbodo, Owonta, Jeddo, Koko and Ogidigbeu.

Finally, there are the areas of least accessibility marked by index line beyond 4500 km. Infact from this line the level of accessibility declines rapidly towards the peripheries in the northern part. The steep decline in accessibility reveals that centres in this zone are not only poorly linked to the central region but are not properly linked to themselves. One cause of this poor accessibility may be poor terrain for some areas of this zone are reclaimed swamplands as in parts of Sapele, Oghara and Adagbrasa. Some areas are also completely covered by water such as Koko, Burutu, Ogbe-Ijoh and Omadino. These represent areas that are farthest from the other centres. They are areas that have least been affected by road improvements.

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 was to consecutively stop at these intermediate centres before reaching Ozoro. Figure 14 presents travel cost valued graph representation of the network by 2016 while figure 15 presents travel time valued graph representation of the network by 2016.

It was discovered that there is generally some relationship between link distance and travel cost. The correlation coefficient was calculated to be $r = 0.86$ (See Appendix A-1). However, this is a global way of comparing the two. It would be more relevant to reduce the cost function to some uniform level. By dividing the link distance into the travel cost along such link we obtain the cost per kilometre along each link. The correlation between link distance and per milometer 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.

In table 7 we calculate the frequency distribution of per kilometre cost along the 56 links observed. The general observation from this table is that there is a difference in per km cost between long and short distance journeys. We observe that for journeys over 11.1km, the per km cost falls between N100:00k and N200:00k, while journeys under 11.1km the cost is between N300:00k and N400:00k. Furthermore for journeys under 5.0km the per km cost falls between N100:00k and N150:00k.

Table 7: Frequency Distribution of per kilometre cost of travelling over 56 links

	Frequency of per km cost (₦)					
Link distance (km)	**0-100**	**101-200**	**201-300**	**301-400**	**Over 400**	**Total frequency**
0 - 5.0	1	0	1	1	0	3
5.1 – 10.1	15	5	4	4	0	28
10.1 – 15.2	2	5	1	2	0	10
15.3 – 20.3	2	3	2	3	1	11
Over 20.3	0	0	2	0	2	4
Total	**20**	**13**	**10**	**10**	**3**	**56**

Source: Fieldwork, (2016)

Table 7 shows that the per kilometre cost tends to be higher over short distances than over long distances. Although this may be a hidden cost (that is, travellers do not normally pay in per kilometre costs), yet the higher cost of short distances may have the effect of making intermediate centres less accessible as travellers would not like to break their journeys for fear of incurring extra costs. Travel time can be differentiated into transit time and waiting time. Transit or driving time describes the period a traveller takes off from the park at the origin point and alights at the park on arriving at his destination point. Waiting time on the other hand refers to the time the traveller waits for the vehicle to arrive or to be fully loaded.

Generally the waiting time is affected by such variations as traffic values, mode of transport and route. Although waiting time may increase the total journey time, it is the driving time, when the traveller has actually boarded the vehicle that determines the time he reaches the destination. The length of time a traveller takes to reach his destination may have a lot of influence on the ability or even willingness to use a particular facility.

Like travel cost two types of driving time can be calculated along the same link that is direct driving time between two major centres, say Asaba and Warri, assuming the driver does not stop enroute and the time considering that driver stop at intermediate centres. Based on these two values of driving time 56 links were considered. It was not however easy to record this direct time accurately as drivers often had cause to stop for various purposes: refuelling, alighting passengers, police checks. Again the driving time so identified is a function of many variables such as the road surface traffic flow, the condition of the vehicle and even the personal disposition of the driver. Because of these factors more detailed data and investigation are necessary to throw greater understanding on the issue than the present study can contain. Here, only a single reading of driving time along a particular link was recorded. It is hoped that this could reveal something about the pattern of accessibility between nodes.

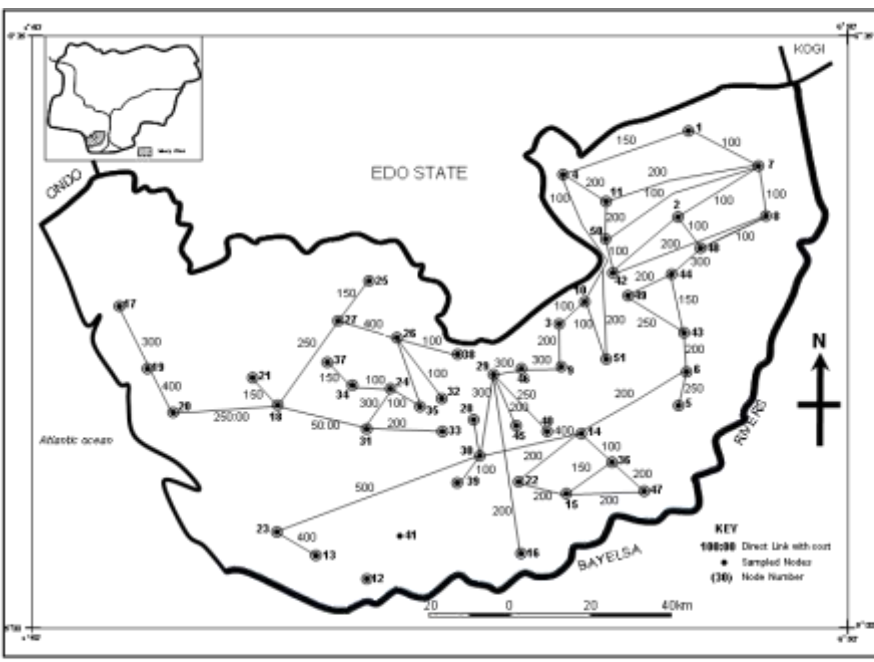

Fig. 14: Graph Representation of Road Network in 2016 with Travel Cost Values
Source: *Fieldwork (2016)*

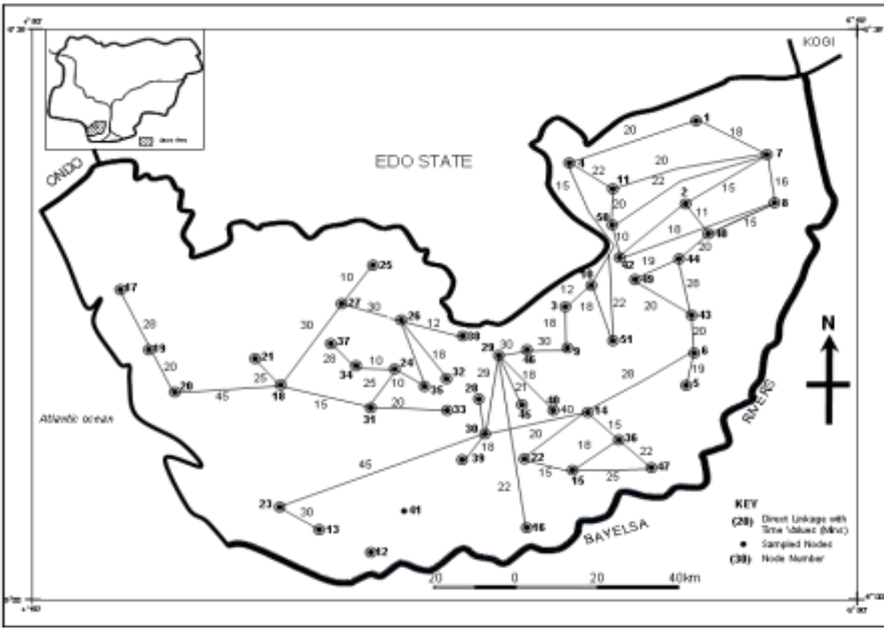

Fig. 15: Graph Representation of Road Network in 2016 with Travel Time Values
Source: *Fieldwork (2016)*

To further investigate the importance of time we can also calculate the average driving speed along each link by dividing the link distance by the driving time. This is given in kilometre per minute (kmpm). The average speed may reveal variations in the nature of the road surface.

The mean driving speed for all nodes of the network was calculated to be 0.57 kmpm approximately 34kmph. The average driving speed was found to be significantly related to the link distance (r = 0.71, Appendix A-2).

However, when the frequencies of observed speeds are grouped according to link distances as given in Table 8 we observe the following points - that majority of the links are concentrated within a distance band of 10.2 – 15.2 km which collectively make up about 56.41% of the observations, that high average driving speeds of over 0.56 kmpm (or 33 kmph) are not common with short distances of under 5.0 km. Rather, speeds of over 0.56 kmpm occur within a distance band of 20.3 and over

25.3 km which makes up about 23.07% of total observation. Ironically on distances of over 25.3 km drivers tend to operate on average speed of under 0.56 kmpm. This apparent low speed on long distance journeys may be attributed to constant stops encounter and the road surface.

Table 8: Frequency distribution of average driving speeds with link distance

	Frequency of average driving speed (km/min)					
Link distance (km)	**0.00-0.10**	**0.20-0.30**	**0.31-0.41**	**0.42-0.52**	**Over 0.52**	**Total**
0 – 5.0	0	0	0	1 2.6%	1 2.6%	2 5.13%
5.1 – 10.1	0	5 12.8%	1 2.6%	1 2.6%	0	7 17.95%
10.1 – 15.2	1 2.6%	7 17.95%	2 5.13%	0	0	10 25.64%
15.3 – 20.3	0	10 25.64%	1 2.6%	0	0	11 28.21%
20.3 – 25.3	0	0	2 8.1%	2 8.1%	1 2.6%	5 12.82%
Over 25.3	0	0	1 2.6%	3 7.7%	0	4 10.25%

Source: Fieldwork, (2016)

Finally, low average speed of under 0.10 kmpm (i.e. 6.0 kmpm) is found within short distances of under 5.0 km. It constitutes about 5.13% of the links. This observed general pattern of average speeds would imply that drivers tend to drive faster within a short distance of 0 – 5.0 km but beyond that their average speed may be reduced by other obstructions such as carrying "half-way" passengers, or refuelling. This would mean that travellers for long distance journeys may not arrive at their destinations as early as they expected if the journey were direct. Thus we find that the Issele-Uku – Agbor road has higher average speed (1.1 kmpm or 66 kmph) than the journey from Effurun to Warri with average speed of about 33 kmph.

Another implication of the observation is that nodes in the study area located at short distance journeys may be just as disadvantaged as those at long distances journey as drivers tends to operate on relatively low speeds. But another factor in addition to the constant need to alight passengers enroute could be urban traffic. The combined effect of all this is to extend driving time beyond the expected.

Policy Implications/Recommendations

The strategy of constructing new links to improve accessibility may involve heavier financial investment. Thus a proper cost benefit analysis may be needed to determine the desirability of such investment. The map on figure 16 contains some suggested new links to be constructed. They were made primarily on the basis that they will increase the accessibility, reduce cost and time to other centres. For example, it will normally take a traveller going to Warri from Kiagbodo some 107.2 km, but when a direct road is connected linking Warri to Kiagbodo it would definitely reduce cost, time and accessibility will increase. The same thing can be said if other centres like Bomadi to Forcados, Ogbe-Ijo to Kiagbodo and Burutu to Aladja (DSC) (see Figs. 6, 14 and 15).

Still another strategy would be to provide those services which cenres lack based on extensive surveys of what are available and what are needed. This centre based approach might prove more useful if the people are guided to choose out of their preference.

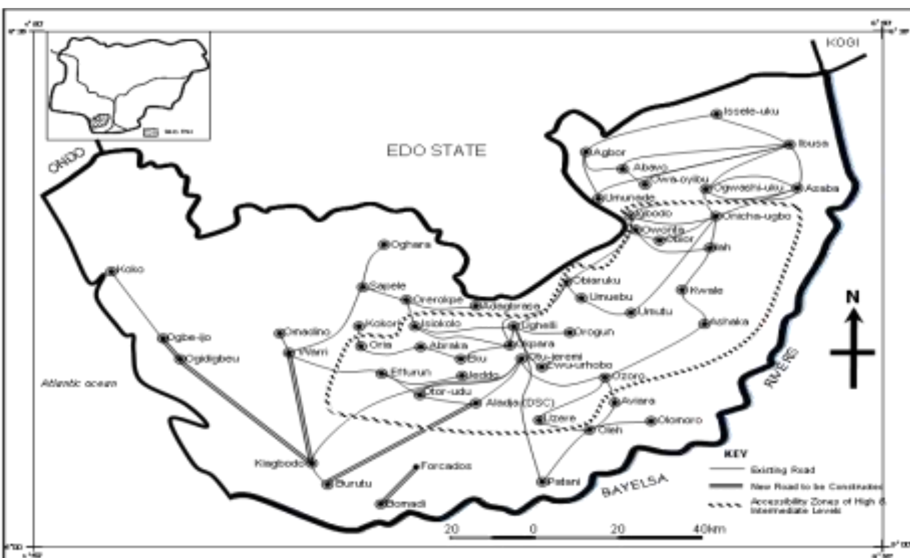

Fig. 16: Suggested Road Improvement Projects

Source: *Fieldwork, (2016)*

In a pilot survey it was found that in Eku, Ewu-Urhobo, Igbodo, Bomadi and Kiagbodo the major facility the centres desired was a commercial bank while at Ughelli and Umutu it was a specialist hospital. In these centres, the nearest commercial bank for Eku is located at Abraka, and for Ughelli the nearest specialist hospital is located at Warri. By providing these cities with the facilities would reduce the distance travelled to obtain these services. This suggestion can be achieved by purchasing structures on the ground.

Conclusion

Rather than merely asking planners what philosophy they assume when making transport and land use plans, it is thought more revealing to internalize the problem. By this it is meant that actual planning cases should be cited and accessibilities to work etc. determined both before and after the plans have taken effect. Access in this case can be thought as a surrogate measure of spatial justice, from which the social justice concept used can he inferred.

Connectivity of a network in this context means the degree of connection between all centres (vertices) or the degree of completeness of the routes (links) between centres (vertices). Apparently the more routes there are in any transportation network the more complex will be the connection between the various centres.

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APPENDICES

APPENDIX A– 1

CORRELATION BETWEEN LINK DISTANCE (LD) AND TRAVEL COST (TC)

Correlation coefficient (r) is given by

$$rLD.TC = \frac{n\left(\sum LD.TC\right)-\left(\sum LD\right)\left(\sum TC\right)}{\sqrt{n\sum LD^2-\left(\sum LD\right)^2\times n\sum TC^2-\left(\sum TC\right)^2}}$$

$$rLD.TC = \frac{56\times 148,200-(640.3)(10,800)}{\sqrt{56\times 9002.97-(640.3)^2\times 56\times 2570500-(10,800)^2}}$$

$$rLD.TC = \frac{8299200-69,5240}{\sqrt{504166-409984.09\times 143948000-116640000}}$$

$$rLD.TC = \frac{1383960}{\sqrt{94182.23\times 27308000}}$$

$$rLD.TC = \frac{1383960}{306.89\times 5225.71}$$

$$rLD.TC = \frac{1383960}{1603718.14}$$

$$rLD.TC = 0.86$$

The correlation coefficient (r) between link distance and travel cost is 0.86. In testing for the significance of the correlation we use the students 't' test which is given by

$$t = \frac{r\sqrt{n-2}}{\sqrt{(1-r^2)}}$$

Where t = Calculated value

r = Correlation coefficient

n = The number of observation

Hence:

$$t = \frac{0.86\sqrt{54}}{\sqrt{(1-0.86^2)}}$$

$$t = \frac{6.32}{0.51}$$

$$t = 12.39$$

Ho = There is no significant relationship between link distance and link cost

Hi = There is some statistically significant relationship between link distance and link cost

Table value n – 2 degree of freedom

56 – 2 = 54

0.01 = 1 – 0.01 = 0.99 or 99%= 2.39

But t cal. > t 0.01

Hence at 0.01 probability level we reject Ho and accept Hi which state that "there is some statistically significant relationship between link distance and link cost.

APPENDIX A – 2

CORRELATION BETWEEN LINK DISTANCE AND AVERAGE DRIVING SPEED

Correlation coefficient between link distance (LD) and average driving speed (ADS) is given by

$$rLD.ADS = \frac{n\left(\sum LD.ADS\right)-\left(\sum LD\right)\left(\sum ADS\right)}{\sqrt{n\sum LD^2-\left(\sum LD\right)^2 \times n\sum ADS^2-\left(\sum ADS\right)^2}}$$

$$rLD.ADS = \frac{56\times 406.11-640.3\times 31.99}{\sqrt{56\times 9002.97-\left(640.3\right)^2\times 56\times 20.22-\left(31.99\right)^2}}$$

$$rLD.ADS = \frac{22742.16-20483.19}{\sqrt{504166.33-409984.09\times 1132.32-1023.36}}$$

$$rLD.ADS = \frac{2258.97}{\sqrt{94182.23\times 108.96}}$$

$$rLD.ADS = \frac{2258.97}{306.89\times 10.44}$$

$$rLD.ADS = \frac{2258.97}{3203.93}$$

$$rLD.ADS = 0.71$$

In testing for significance of the correlation we use the students 't' test which is given by

$$t = \frac{r\sqrt{n-2}}{\sqrt{\left(1-r^2\right)}}$$

Where r = 0.71, n = 56

Hence:

$$t = \frac{0.71\sqrt{54}}{\sqrt{\left(1-0.71^2\right)}}$$

$$t = \frac{5.22}{0.49}$$

$$t = 10.65$$

Ho = There is no significant relationship between link distance and average driving speed.

Hi = There is some statistically significant relationship between link distance and average driving speed.

Table value n – 2 degree of freedom
56 – 2 = 54

0.01 = 1 – 0.01 = 0.99 or 99% = 2.39

But t cal. > t 0.01

Hence at 0.01 probability level we reject Ho and accept Hi which state that "there is some statistically significant relationship between link distance and average driving speed.