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Original Research Article

Analysis of Rail-Road Network Connectivity and Accessibility with Selected Nigerian Seaports

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This study analysed railroad network connectivity and accessibility with selected Nigerian seaports. Specifically, the study analysed the level of connectivity and accessibility of railroad network with the Inland Container Depots (ICDs) and Container Freight Stations (CFSs). Secondary data with the aid of ArcGIS, (2012) software (a geographical information system working with maps) was analysed using Connectivity Index and Shimmel Analysis to determine the level of connectivity and accessibility of Nigerian road-rail network with the proposed ICDs and CFSs. The study revealed that rail network was only pronounced in two ports (Lagos and Port Harcourt ports) in Nigeria. This research work concluded that rail transport is more viable to haul goods from Nigerian ports to various ICDs and CFSs. Results from analysis of connectivity and accessibility of the railroad network emphasized that road network is more connected than rail, but rail network is more accessible to ICDs and CFSs. Therefore, it is suggested that road transport should complement rail transport by transporting from and to lesser distance(s) where rail transport has discharged so as to enhance intermodalism especially in shipping logistics operations.

Keywords Accessibility, Connectivity, Network, Seaport, Rail-Road

INTRODUCTION

Nigeria is one of the maritime countries in which the availability of coaster resources has made water transport possible. The economy is highly dependent on importation of goods (like, machineries and equipment, chemicals, etc.) and exportation of crude oil, agricultural products and other general goods. The presence of maritime transportation has enabled the Nigerian government to associate and relate to the rest of the world, especially maritime nations (Badejo, 1998).

Historically, Nigerian shipping logistics have been moving materials and products through rail and road networks. The configuration of the transportation network of a country determines the level of connectivity and accessibility for movements. A network is a combination of several routes into a more or less integrated structure, permitting movements between many modes (Okoko, 2006). The configuration of the transportation network of a country determines the level of connectivity and accessibility for movements. A network is a combination of several routes into a more or less integrated structure, permitting movements between many modes

(Okoko, 2006). Networks differ in concentration, extent and efficiency, and result from various physical, cultural, technological and economic factors (Hagget&Chorley, 1969). The inefficient and below par condition of the transportation networks in Nigeria, no doubt has resulted in the poor performance of the network (Stephen 1998 & John, 2005).

Shipping logistics are increasingly witnessing applications of series of approach to solve the global supply chain and myriads of shipping logistics problems. Ports are particularly affected by ever increasing container volumes as their operational capability becomes highly constrained. Increase in container volumes causes increased pressure on entire logistics network resulting in congestion, high dwell time and higher logistics costs (Japan International Cooperation Agency, 2009; Arvis et al, 2010; UNCTAD, 2009). In light of these constraints, ports have embarked on the implementation of inland container depots (ICDs) as operational and capacity enhancement strategy for easing the pressure on congested maritime terminals (Haralambides and Gujar, 2011).

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According to Haralambides&Gujar, (2011); Implementation of ICDs unleashes a set of new challenges upon the containerized supply chain. Challenges include effective determination of location and number of depots to insert in the logistics network. Likewise, the allocation of container boxes to each depot and their ultimate routing to the final destination in a way that minimizes the transportation cost born by shippers and the economy at large needs to be examined further. Hence; in this research, a careful observation of shipping logistics in Nigeria analyzed the strengths and weaknesses of available modes of transportation and their current operations bearing in mind what it is and what it should be. The analysis of logistics system for all activities is to ensure that materials and products are at the right place, at the right time in the right quantity and in good condition satisfying place and time utility.

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Some earlier works (Garrison & Marble, 1960; Kansky, 1963; Harggett & Chorley, 1969) exclusively focused on topology measures adopting graph-theoretic network analysis but were constrained by limited data, computational power, and modelling techniques. In transport network analysis, when a transport network is represented conventionally as a graph, the links in the network become edges in the graph and the nodes (junctions) are the vertices. In analyzing the graph, the edges were defined by major thoroughfares intersecting to provide vertices. In dealing with the intra-urban road network, not all roadways may be included, but major thoroughfares that reflect relevant linkages of the transport network. This involves an analysis of the incidence structure of the networks to provide an initial set of accessibility measures and binary connectivity matrix prepared from where Shimbel index showing a measure of nodal accessibility.

Similarly, (Burgess, 1925; Hoyt, 1939; Harris & Ullman, 1951) generally believes that sites adjacent to main transport routes have relative advantages over those located some distance away, and other sites located at route intersections possess a relative advantage with greater advantages belonging to sites located at focus on the transport system. These advantages are determined in relation to accessibility, which has different characteristics in relation to individual sites thus differentiating between sites in terms of accessibility advantages. A transportation network has experienced an evolution of terminals which connect seaports with their hinterlands. In order to gain access to these terminals, there must be connectivity and accessibility through transportation multimodal networks. Researchers in the past had traced shipping logistics accessibility and connectivity problems to the conditions of general transportation infrastructure in Nigeria.

Somuyiwa (2008) argued that; Shipping logistics problems can be attributed to traffic congestion encompassing major seaports and long queues at container terminal gates, which is a primary source of air pollution; increased energy consumption, loss of revenue for low-margin truck drayage operators, and damaged transportation infrastructure caused by the number of container-bearing trucks on the roadway are other problems created by increased volume and poor cargo-clearance capabilities. Obafemi (2011) conducted a survey that showcase that the state of Nigerian roads (the infrastructure in transportation network) remains poor for a

number of reasons such as faulty designs, lack of drainage and very thin coatings that were easily washed away, excessive use of the road network given the underdeveloped nature of waterways and railways among others. Most railway lines in developed countries have dual tracks. This is not the case in Nigeria. In Nigeria, dual tracks are found only at the railway stations. Normally, the spatial distance between two rail stations should not be more than 15km. When stations are few distances apart, it makes it easy for trains coming from opposite directions to give each other right of way (shunting) (Okoko, 2006). In Nigeria, the stations are widely scattered, and because they are mostly single-track rails, one train must wait at a station for a long time for the arrival of the other, before it can proceed on its journey.

Nigerian railway is still using the narrow gauge of 3ft6inches (106.68 or approx.107cm) instead of the standard gage of 4ft8 1/2 inches (143cm) or the broad gauge of 5ft3 inches (106cm). The narrow gauge does not give any room for speed and cannot accommodate modern coaches or wagons. The signalling equipment for the rail transport is very expensive, and the one in use now in Nigeria is obsolete (Okoko, 2006). The reliance on road transport and lack of operational port-rail links in Nigeria results in severe congestion and its negative multiplier effect is crucial and may be low productivity (Botha and Filani, 2006). In Nigeria, multi-transport and door to door services are seriously constrained by the poor condition of inland transport system. Indeed, road and rail links with ports are often inadequate to promote door to door services (Anderson, 1998).

Somuyiwa (2008) also revealed that; Apapa port is faced with the problem of traffic congestion, as a result of the predominance use of only road mode of transport system for movement of these cargoes. Ubogu (2008) conducted a survey on the number of trucks that loaded per day at Lagos and Rivers complex; discovered that 2063 trucks loaded daily from Apapa Wharf, Tin Can, Port Harcourt and Onne seaports in 2008. This account for the pressure exerts on road transport by heavy duties with attendant deplorable state of roads in Nigeria. Our ports operations are not adequately computerized to facilitate quick cargo clearance, unlike in countries like Singapore where their ports Information Technology (IT) developed in the early 80s such systems as their trade net and port-net application, GPS, GIS and GNSS which are instrumental in speeding up documentation and cargo clearance (Oni, 2007).

Port operations and planning, marketing and competition, performance measurement and monitoring systems, were almost entirely directed towards sea transport and shipping services, with little/ no emphasis on inland transport services, and much less on landside logistics operations, services, and facilities (UNTACD, 2004). Lack of sufficient storage capacity in terminals due to lack of adequate land as well as the increasing level of congestion associated with cargo movement within and outside the terminals motivates different approaches to deal with the situation. In a study of rural accessibility problems in Kwara State, Ogunsanya (1986) noted that the poor rural situation result from inadequacy of both networks and vehicles.

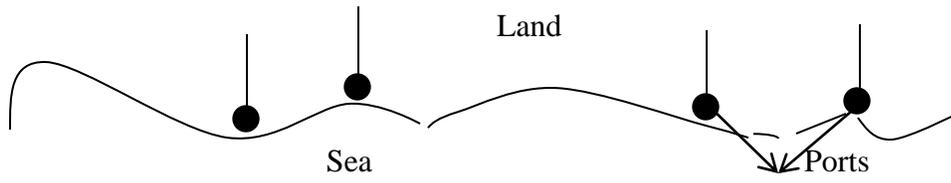


Fig 2.1: Littoral Settlements
Source: (Okoko, 2006)

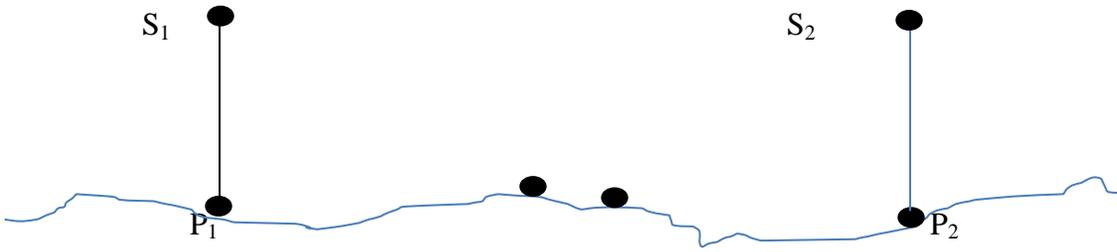


Fig 2.2: Penetration Lines and Port Concentration
Source: (Okoko, 2006)

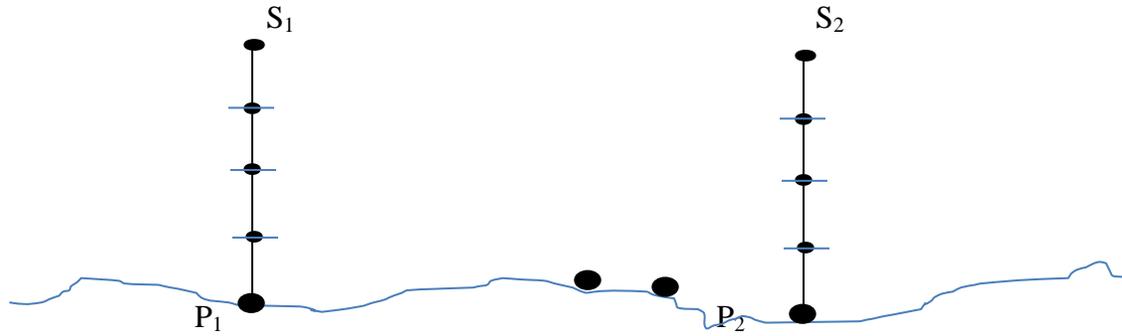


Fig 2.3: Development of Feeders
Source: (Okoko, 2006)

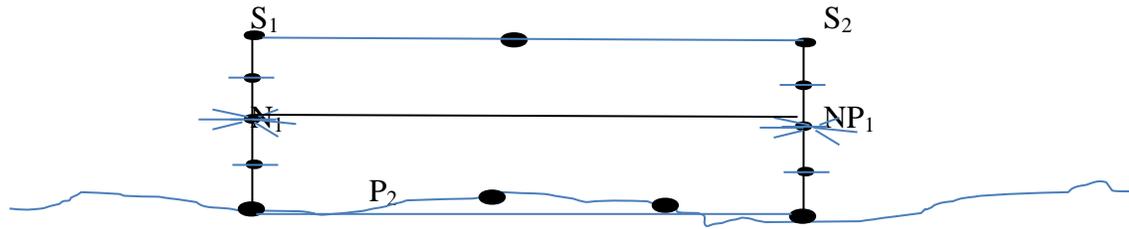


Fig 2.4: Beginning of interconnection
Source: (Okoko, 2006)

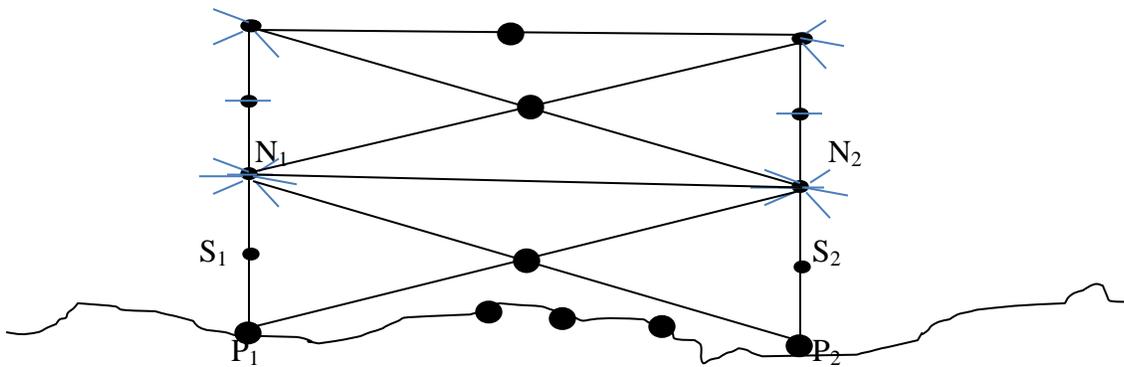


Fig 2.5: Complete Interconnection
Source: (Okoko, 2006)

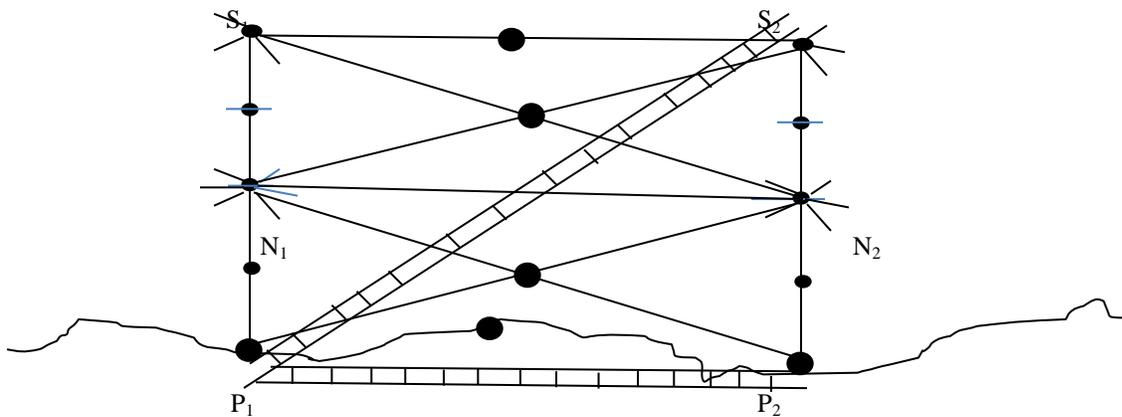


Fig 2.6: Growth of high-priority main streets.
Source: (Okoko, 2006)

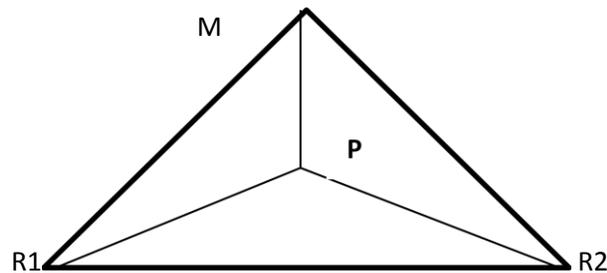


Fig 2:14: Weberian Triangle

Source: Whyhne-Hammond (1979)

Graph Theory

The use of graph theory measures allows us to understand how objects covering the surface interact and what the implications they have on spatial organization (Taaffe and Gauthier, 1973). Taaffe, Morill and Gould (1963) developed models based on the emergence of transport network in Nigeria and Ghana. This model is made up of six sequential or episodic stages:

Stage 1: At this stage, there is no transport network; rather there are a number of small coaster ports and trading posts. Each of these coaster ports has a limited hinterland which it serves.

Stage 2: At this stage, two of the coaster seaports (P1 and P2) grow in economic and political prominence and eventually establish links with two hinterland settlements (S1 and S2). The two hinterland settlements could be political or administrative centres or centres rich in some natural or mineral resources (see the figure below)

Stage 3: At this stage, the two prominent seaports highlighted in the previous stages expand their control of the hinterland at the expense of all the other smaller ports. In the process, smaller settlements develop along the major routes or penetration lines and these also have controls over other smaller areas of the hinterland.

Stage 4: This is the stage where the feeder or intervening settlements now have a sizeable control over a given area of the hinterland (N1 and N2) and communication routes begin to connect some of the bigger settlements.

Stage 5: At this stage, there is a linkage of all the major settlements by roads. This marks the stage when there is economic advancement in the region and communications networks are completely interconnected.

Stage 6: This is the final stage in the development of a transport network. At this stage, the network is fully developed and high-priority main streets are constructed in the region to facilitate movement and economic growth.

Transport structures, or networks, are integrated patterns in which groups of centres (nodes) are linked by set routes (Whyhne-Hammond, 1979, Okoko, 2006).

Location theory

The neo-classical or Weberian location theory evolved around cost minimization triangles. This theory is probably the most important theory based on least transport cost considerations and his task was to use the least transport

cost to determine the optimum site for the location of industries (Okoko, 2006). He assumed that there are two points where raw materials could be obtained, and a single site for market and his task, therefore was to determine the least cost location for industries. In the first postulation, it is assumed that transport costs are the same for the finished goods and for both raw materials.

That is, it costs the firm the same for bringing its raw materials into the plant as it does for its finished products to the market (Whyhne-Hammond, 1979). In this arrangement, point P where the industry is to be located is at the centre and it is joined by isodaplanes (lines of equal total transport costs) to the raw material sites and the market. M= Market ; R1,R2= Raw materials site, P= least-cost location

Optimum location revolves around the cost of materials and transportation costs: exogenous changes in costs can lead to alterations in the input mix of raw materials or to a new location.

Components of shipping logistics in Nigeria

Logistics management requires all components of the intermodal freight transportation process to be reliable, offer connectivity with other modes and have the flexibility to make changes when alternative business opportunity develop, while the freight is still in transit (Somuyiwa,2008). Inter-modalism therefore becomes a major component of the system approach to business, which is an integral part of what commonly called logistics management. However, effective shipping logistics should be reliable, safe, secured and provide frequent deliveries.Perhaps of importance in logistics infrastructure is an untapped waterway or River Niger that can assist in decongestion of the Apapa port area,as well as playing hub port role to all neighbouring countries (Somuyiwa,2008).

Transportation Modes

The key element in the logistics chain is transportation system which joins separate activities together. Transportation occupies one-third of the amount in logistics cost and transportation systems influences the performance of logistics systems greatly -(Chang, 1988). Research in the field of supply-chain management argues that transportation often represents one of the chain's weaker elements. Rail transport is the oldest model in

Nigeria apart from normal foot paths. It began in 1898 with Lagos to Ibadan line that was completed in 1901. Its original conception by the colonial authorities was to open up the country to trade with England as well as an instrument of administrative control, regional growth and development, politics and military control (Robinson, 1961; Ademiluyi 2006a).

Truck: Majorly in Nigeria, trucks and trailers according to the official website of statistics of Nigerian Port Authority (NPA) are responsible for 99.7% of goods haulage. Trucking advantages are its door to door service.

Maritime: Ship is a major component in maritime operations. The route of maritime transport is oceans and seas. According to Somuyiwa (2008): There are many navigable rivers in Nigeria that includes: River Niger, Benue, Hadejia and many others. The Nigeria Inland Waterways Network is reputed to be one of the longest in the world spanning over 3000 kilometres. It consists of 50 Rivers, including Rivers Niger, Benue, Cross River, Kaduna, Imo, Ogun, Sokoto and Lakes in Oguta and Chad. However, this great transport resource is still underutilized. Nigerian shipping logistics have failed to make use of the potentialities of inland waterways to distribute goods effectively across the country. Inland water transport recorded significant growth in Nigeria in the 50s and early 60s when major river operators such as Niger River Transport Limited (NRT) and Holts Transport Limited (LT) moved total annual freight tonnage of up to 259,000 tons.

Road: Nigerian roads, especially relating to this study linking ports and hinterland sometimes are full of potholes that are responsible for breakage of vehicles along the major roads resulting to incessant traffic jams, congestion and environmental pollution. The road seems to contribute to often break-down of vehicles, even with proper maintenance. However, Road transportation charges are more than rail transportation charges (Ubogu, 2011). Cost of fuel accounts for more than 50 percent of the running cost of truck, heavy labour charges engaged in unloading, road traffic congestion because of bad road conditions, i.e. loss of time and money contributes to higher transportation charges. However, road transport continues to be the preferred choice because unlike the railways, road transport provides door-to-door service. The major function of the transport system of any country is the efficient delivery of goods in the fastest and cheapest way possible (Rapu and Ayoade, 1996).

Warehousing: Warehousing is a traditional approach in which goods are received by warehouses and stored in tanks, pallet racks or on shelves. When an order arrives, items are retrieved, packed and shipped to the customer. Warehousing consists of four major functions: reception of the incoming goods, storage, order picking and shipping.

Inland Container Depots: Having realized the importance of depot for onward movement and effective distribution of goods throughout the country, Nigeria proposed the establishment of inland container depots across strategically located points so as to serve the entire six (geopolitical zones) of the nation.

METHODOLOGY

The Study Area

Nigeria is a country which lies between Latitude 40N to 140N of the equator and Longitude 30E and 150E of the Greenwich Meridian (Filani, 1995). According to (Bamigbola, 2007): The major ports in Nigeria are: (Lagos Port Complex: Apapa, Container Terminal Apapa, Tin Can Island Lagos, RoRo Port, Lagos, Warri port, Port-Harcourt port, Onne Port and Calabar port. Among the crude oil terminals in Nigeria include; Escravo, Bonny, Sapele, Forcados, Tuma and Okrika and other ports like Akasaport, Burutuport, Koko Port including Kirikiri Lighter terminal, Lagos and Federal Lighter terminal Ikorodu. CFS Zamfara, Kastina state (10,000 metric tons), Bulunku Borno State (10,000 metric tons), ICD Heipang Plateau State (20000 metric tons), Zawanchiki, Kano State, (20000 metric tons), Erunmu, Oyo State (50000 metric tons), Ntighalsiala Abia State (50000 metric tons), Galambi Bauchi and Kuku Gombe states (FRN official gazette 2007).

In an attempt to determine the relative accessibility and connectivity index (es) of the railroad in the study area, the map of railroads will be converted into graph regardless of the width, quality, and standard of the rail-roads. As at today, the rail network in the country stands at 3,557 kilometers with 3,505 kilometers still on the narrow gauge. While the rails stagnated, the roads are lengthened. As at 2005, about 193, 200 kilometres of roads were available in the country. Of these 34, 123 kilometers are federal roads, 30, 5000 kilometers are states', and 129, 577 kilometers are local council roads. These roads carry more than 90 per cent of domestic freight and passengers. The result was that too much pressure was brought to bear on the available road infrastructure, thereby causing incessant collapse and necessary huge financial outlay for maintenance and repairs (Oshin & Siji, 1990).

RESULT AND DISCUSSION

Analysis of Connectivity by Rail

Alpha Index: It is one of the most useful and perhaps the best measure of the connectivity of a network. Alpha Index (α): expresses the ratio of the number of circuits to maximum possible in a network

$\alpha = \text{Alpha index}$

e = the number of links (i.e edges or arcs) in a network

V = the number of vertices in the network

For fig 4.1; i.e connectivity of rail network

$$\alpha = \frac{e - V + S}{(2V - 5) \times 100}$$

$= \frac{11 - 10 + 0}{(2(10) - 5)} = \frac{1}{15} = 0.066 = 6.6\%$. This shows that the network is poorly integrated.

Beta Index (β)

The Beta index indicates the ratio of connectivity between the links and the nodes in a network.

$\beta = \text{links/node}$

$$\beta = \frac{e}{v} = \frac{11}{10} = 1.11$$

The

significance of β is $0.5 \geq \beta \geq 3.0$

The value above revealed that the network is less averagely connected as it is less than 3.0

Nigerian Map of the Rail network

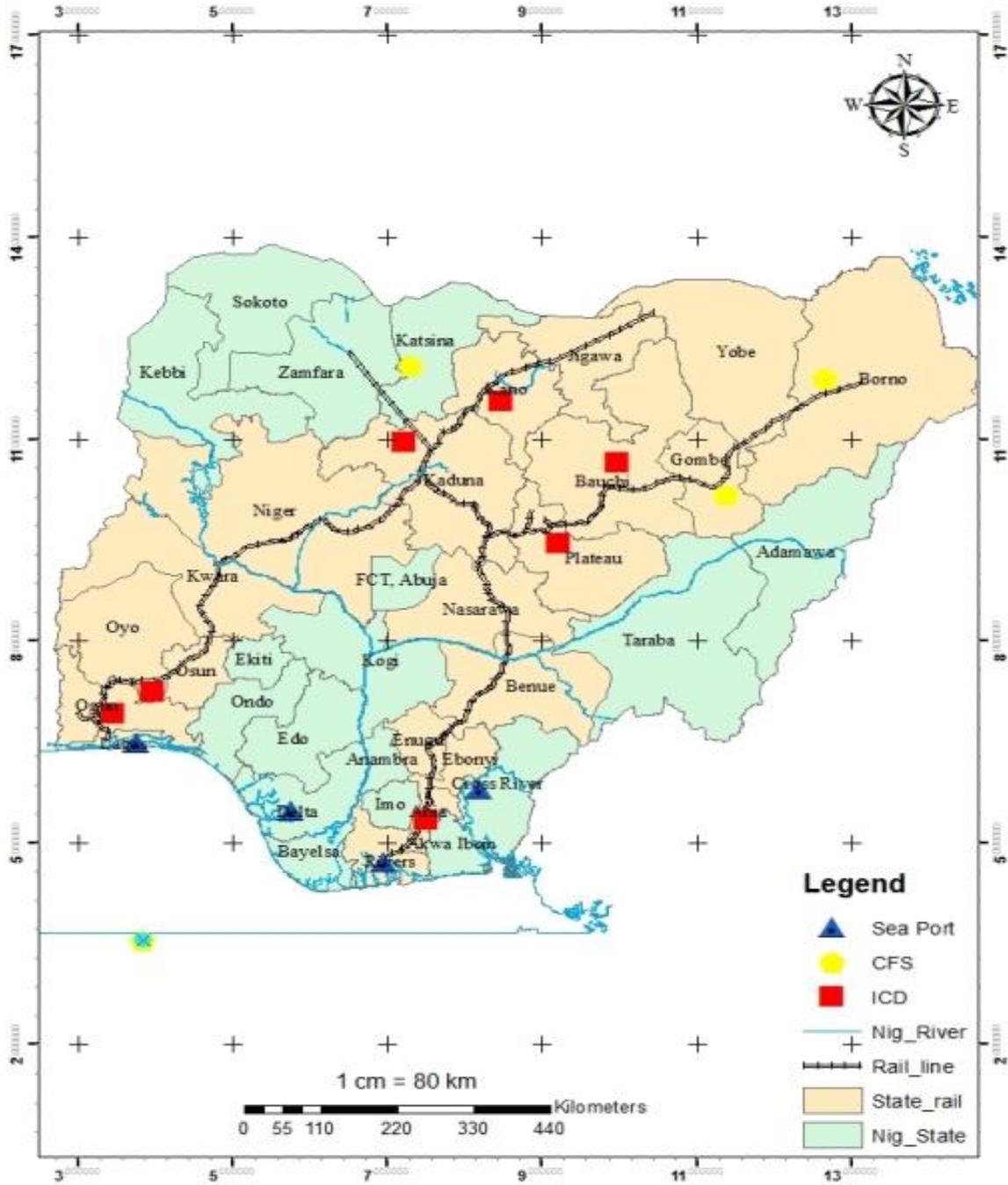


Fig 3.1: Existing Rail Network of the study area
 Source: Authors' Computation (2015)

Gamma index

It is the ratio of the number of arcs in a network to the maximum, which may exist between a specified number of vertices or to the maximum possible in that network.

$$\gamma = e / 3(V-2) = 11/3(10-2) = 11/24 = 0.45 \times 100 = 45\%$$

The significance of $\gamma = 0 \geq \gamma \leq 1$

The above γ calculation revealed that the network is connected at 45% level.

Analysis of road network connectivity

$$\alpha = e - V + S / (2V - 5)$$

$$= 23 - 16 + 0 / (2(16) - 5) = 7/27 = 0.26$$

$$\beta = e/v = 23/16 = 1.44$$

The

significance of β is $0.5 \geq \beta \geq 3.0$

$$\gamma = e / 3(V-2) = 23/3(16-2) = 23/42 = 0.55$$

The

significance of $\gamma = 0 \geq \gamma \leq 1$

From the above calculations, $0.26 \times 100 = 26\%$. The road network to the ICDs and CFSs is poorly integrated too. The β value of 1.44 shows that the network is averagely connected as it is above 0.5. The γ value revealed that the network is connected at the 55% level of significance.

The road network is more integrated and more connected to the ICDs than Rail Network. Connectivity index is used to express the relationship between the number of nodes and the number of links in a single network. From the connectivity calculations above, Alpha index (α) is the only index that reflects poor connectivity of the network. Whereas, Beta (β) and Gamma (γ) reflected 1.11 and 45% level which depicts average connectivity. The above shows that there is need to increase the links and the nodes of the network in Nigerian shipping logistics. From the table 4.1, it has been revealed that the Inland Container Depots of Plateau and that of newly constructed in Kaduna are the most connected and also most accessible. The Connectivity Index (CI) of 0.44 for both depots justifies the reason why they are the most connected and accessible. However, Kastina Container Freight Station (CFS) is not connected by rail transport network. Hence, the need to channel rail track from any of the neighbouring states like Zamfara, Kaduna or Kano.

The analysis revealed that Rail Network is pronounced in the two ports (i.e Lagos ports and Porthacourts) are channeled to Rail network in Nigeria. Therefore, it will be difficult to transport goods from Delta ports and Cross Rivers Ports by rail mode of transport. Although; Cross river is closer to the ICD in Abia, still transportation by rail may be difficult and perhaps inland waterways may be very useful as an instrument of connectivity. Similarly, Delta ports have to make use of Rivers should it wants to transport good and services by rail mode of transport. Ifo and Borno with Hi of 0.11 each are the least connected and least accessible. While Erunmu, Bauchi, Gombe, Abia and Kano with Hi of 0.22 can be said to be the half of the highest connectivity and accessibility value.

Comparative Analysis of Road-Rail Network to the Ports

Comparing the rail and road modes of transport to the various container depots indicated that the strengths of rail and road at closer distance (Ifo and Erunmu) are the same. But the rail transport is stronger as the distance increases. However, the time that may be wasted loading the wagons

of trains may offset the advantage of large volumes of goods usually considered advantageous for rail transport.

CONCLUSION AND RECOMMENDATION

This research work concluded that rail transport is more viable to haul goods from Nigerian ports to various ICDs and CFSs. Results from analysis of connectivity and accessibility of the railroad network emphasized that the road network is more connected than rail, but rail network is more accessible to ICDs and CFSs. Therefore, it is suggested that road transport should complement rail transport by transporting from and to lesser distance where rail transport has discharged so as to enhance intermodalism especially in shipping logistics operations. Secondly, the rail network in Nigeria is just a single track for both onward and reverse logistics as expressed by Okoko (2006). This invariably will cause delay as the train will have to wait for one another in the cause of movement. To make the matter worst is the fact that, the rail tracks are not evenly and well connected for effective shipping logistics operations. Having the tracks from South to North is not only a problem but making it evenly constructed across the eastern part of Nigeria as well as North –West is highly important. What perhaps makes the road to be more considered than rail mode of transport in shipping logistics may be the amount of time wasted at the ports loading the wagons compared to loading trucks which may be faster.

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Table 4.1: Analysis using Shimmel Index (SI) for Rail Accessibility

	Ifo	Erunmu	kaduna	Kastina	Kano	Plateau	Bauchi	Gombe	Borno	Abia	CI	Si= CI/N-1
Ifo	-	1	2	-	2	2	3	4	5	2	21	2.33
Erunmu	1	-	1	-	1	1	2	3	4	1	14	1.55
Kaduna	2	1	-	-	1	1	2	3	4	1	15	1.66
Kastina	-	-	-	-	-	-	-	-	-	-	-	-
Kano	2	1	1	-	-	1	2	3	4	1	15	1.66
Plateau	2	1	1	-	1	-	1	2	3	1	12	1.33
Bauchi	3	2	2	-	2	1	-	1	2	2	15	1.66
Gombe	4	3	3	-	3	2	1	-	1	3	20	2.22
Borno	5	4	4	-	4	3	2	1	-	4	27	3.00
Abia	2	1	1	-	1	1	2	3	4	-	15	1.66

Source: Author's Computation (2015)

Table 4.2: Shimbel Analysis of Accessibility by Road

	Ifo	Erunmu	kaduna	Kastina	Kano	Plateau	Bauchi	Gombe	Borno	Abia	CI	Si= CI/N- 1
Ifo	-	1	2	3	3	2	2	3	4	1	21	2.33
Erunmu	1	-	1	2	2	1	1	2	3	1	14	1.55
Kaduna	2	1	-	1	1	1	2	3	4	2	17	1.88
Kastina	3	2	1	-	2	2	3	4	5	3	25	2.77
Kano	3	2	1	2	-	1	2	3	4	2	20	2.22
Plateau	2	1	1	2	1	-	1	2	3	1	14	1.55
Bauchi	2	1	2	3	2	1	-	1	2	2	16	1.77
Gombe	3	2	3	4	3	2	1	-	1	2	21	2.33
Borno	4	3	4	5	4	3	2	1	-	3	29	3.22
Abia	1	2	2	3	2	1	1	2	3	-	17	1.88

Source: Author's Computation (2015)

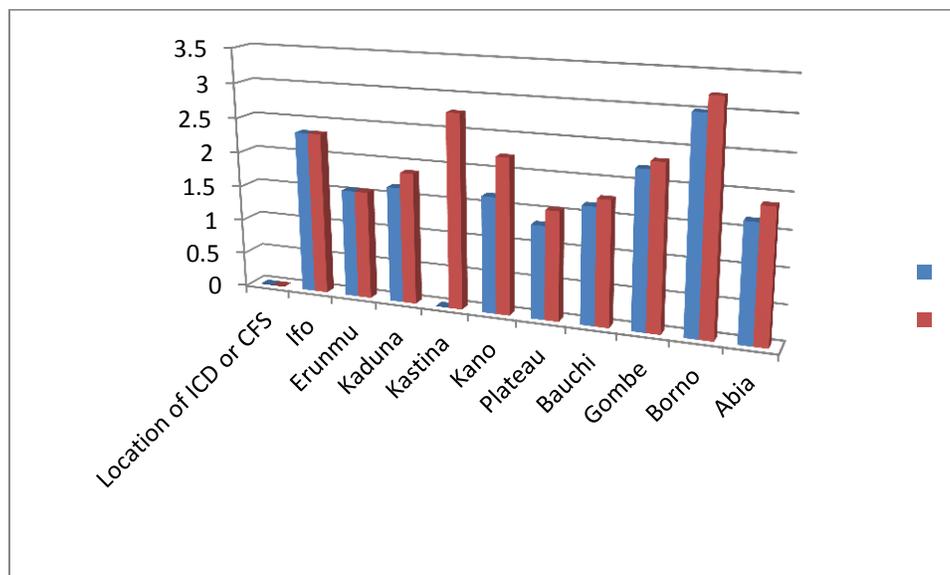


Fig 5.1: Comparative Analysis between railroad network to ICDs and CFS
Source: Authors' Computation (2015)