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Spatial Distribution of the Rail Freight Demand in Nigeria Prior To Railway Reform

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Abstract:

A virile rail mode of transportation plays a significant role in the sectoral development and overall growth of any economy. It opens up regions, hinterlands and rural areas by facilitating agricultural development as well as the growth of large-scale industries. Starting in 2004, a reform process in the Nigerian rail freight sector resulted in liberalisation in 2021. This paper assesses the state of the demand before the liberalisation using rail commodity flow data of 2004–2021 period. With the GIS-based analyses, the study discusses the demand characteristics for city-based and station-based production/attraction values to detect important load centres and corridors for rail freight demand. The results include major rail commodity flows and origins-destinations in terms of transported net weights and revenue earnings. The evaluation of the relationship between city-based rail freight demand and gross domestic product (GDP) values showed that the origins/destinations of significant rail freight are not necessarily the most industrialised cities, but those are either port or mineral ore producing ones. The findings of the study are expected to help new entrants and incumbent companies, including domestic or international ones, to compete in the freight market and offer competitive and reliable service to existing rail customers. This will attract new customers and thus, will hopefully contribute to the modal shift to rail from other modes of transport.

Keywords: *Transportation Rail freight, Demand characteristics, Nigeria, Liberalisation, Geographic Information Systems (GIS)*

1. Introduction

Railways helped the industrial revolution by efficiently transporting raw materials from the ports to the factories (Nalçakan, 2009). Rail and maritime shipping are the most energy-efficient modes of freight transportation (Rodrigue, 2017). However, railways lost freight transportation due to external (economic crises, inability to adapt to competitive market needs, increased fiscal deficits) and internal (deterioration in service quality, resistance to innovation) factors in the mid-20th century (Eisenkopf, 2006). After the 1970s, road freight transport gained market share by offering door-to-door and customized services (and more recently air transportation). By the 1990s, it had lost much of its allure and depended on public funds. Improving efficiency of vehicles, weak international cooperation among railway (and other modes) undertakings, lack of cross-border technical harmonisation, and changing market demands all exacerbate the situation.

Transportation of freight is critical to the economies of both developing (Nigeria) and developed countries. By increasing the competitiveness of industries and businesses, a reliable and time- and cost-effective freight movement can have a significant impact on economic development and prosperity. Total logistics costs must be minimized. This includes transportation, warehousing, inventory management, handling, and modal transfer in ports/terminals. Additionally, goods must be delivered on time and effectively. To accomplish these objectives, various railway operational models have been developed. Nash (2016) identifies three fundamental organizational models: I state-owned monopolies (as in Russia, India, Nigeria, and China), ii) deregulated private vertically integrated firms (as in the

United States and Japan), and iii) infrastructure-operations separation (e.g., in European countries and Nigeria-recently). Through various directives and railway reform packages, Europe's national railway networks (i.e., infrastructure) are being separated from operations and reshaped to make railway operations competitive with other modes of transportation, to establish an integrated railway network, to eliminate the heavy economic burden imposed by incumbent railway companies, to reduce CO2 emissions, and to decouple increasing mobility from gross domestic product (GDP) (Russo, 2015; Zunder, Islam, Mortimer, & Aditjandra, 2013). Nigeria implemented its railway reforms between 2004 and 2021, in response to European railway reform initiatives.

1.1Brief History of The Early Development and Decline Nigerian Railway Industry

Rail transportation has enormous potential due to its relative safety, dependability, and cheap cost to users and its unique capacity to revolutionise the national economy through a mass movement of people, products, and services (Sietchiping Permezel and Ngomsi, 2012). The necessity for a working railway system and the enormous potential for lucrative rail infrastructure investment in Nigeria are unavoidable in this context. Nigeria began establishing its railway network in 1896, making it one of the world's earliest. (2012) (Odeleye) According to Kakumoto, London's first train ran in 1863, whereas Japan's first train ran in 1872. (Kakumoto, 1997; A. O. Joshua, 2012). The Nigerian Railway Corporation (NRC) was established under the 1995 Act to run the country's rail infrastructure, which includes 3,505 kilometres (1,067 kilometres) of 3 ft 6-inch (1,067 mm) Cape gauge lines and 507 kilometres (1,067 kilometres) of standard gauge lines. Nigeria's railways use the same track gauge as the bulk of Britain's African possessions. The Western Line, which spans 1,126 kilometres between Lagos on the Bight of Benin and Nguru in the north-eastern state of Yobe, is one of two main Cape-gauge rail lines in Nigeria (700 mi). (2012); Manji Y., 2020) (Joshua A. O., 2012; Manji Y., 2020)

The Eastern Line connects Port Harcourt in the Niger Delta with Maiduguri in Borno's north-eastern state of Borno, close to the Chadian border (Manji Y., 2020). According to the Infrastructure Concession Regulatory Commission (ICRC), there are also additional branch lines, as described by Manji Y., 2020, according to the Infrastructure Concession Regulatory Commission (ICRC).

a. The Linking Line connects Kaduna to Kafanchan on the Eastern Line through the Western Line.
b. Ifaw–Ilaro, 20 kilometres (Western Line) (12 mi)
c. Minna–Baro (Western Line), approximately 150 kilometres (93 mi)
d. 245-kilometer-long Zaria–Kaura Namoda (Western Line) (152 mi).
e. Kuru–Jos, 55 kilometers (Eastern Line) (34 mi)
f. 200-kilometer-long Baro-Kano Railway Station (Northern Line) (120 mi).

With a gauge of 2 ft 6 in (762 mm), the Bauchi Light Railway stretched 143 miles between Zaria and Bukuru and was constructed in sections between 1912 and 1914. (Manji Y., 2020). Between Jos and Bukuru, a ten-mile segment was converted to 3 ft 6 in (1,067 mm) gauge in 1927 and became part of the Kafanchan to Jos branch line (Manji Y., 2020). The 2ft 6in the Zaria-Jos section remained in service until 1957, when it was deactivated (Manji Y., 2020). Additionally, there was a brief existence of the 2ft 6in gauge Wushishi Tramway, which began in 1901 and connected Wushishi to Zungeru (12 miles) before being expanded to Bari-Juko in 1902. (10 kilometres). (Y. Manji, 2020) After the Hunslet-built 0-6-2T locomotives were retired in 1911, they were transferred to the Bauchi Light Railway (Manji Y., 2020). It is also necessary to include the Lagos Steam Tramway (1902) and the Lagos Sanitary Tramway (1906), both of which have 2ft 6in gauge (Manji Y., 2020). There are no railway connections with adjacent nations since Nigeria does not employ the same track gauge as its neighbours, whose metre gauge railway networks were built by the French and German colonial regimes (Manji Y., 2020). Rail links to Niger were proposed via Illela in Sokoto state and Cameroon, but they were not constructed (Manji Y., 2020).

The Nigerian Railway Corporation (NRC) had a precipitous drop due to inadequate enforcement, implementation, and monitoring, as well as a lack of revision of the 1995 Act. This decline was evident over decades in terms of insufficient passenger and freight traffic. Rail lines' capacity and utility have been eroded as a result of outdated locomotives and train stock. Table 1.1 cover the years 1964 to 2003 and include passenger and freight traffic (Manji Y., 2020). By early 2013, Nigeria's rail network had only one operable stretch between Lagos and Kano (Manji Y., 2020). At an average speed of 45 kilometres per hour, passenger trains completed the journey in 31 hours. Without a doubt, these developments and the requirement to examine the whole Act of the Nigerian Railway Corporation (NRC) demanded different legislations.

1.2.Liberalisation in Nigerian Rail System

The repeal and re-enactment of the Nigerian Railway Corporation Act CAP N129, LFN 2004, 2015 (SB. 001) aimed to revitalise and enhance the operating framework and remove restrictions that had previously been removed hampered international best practices in the rail transport sector. Nigeria maintained an excellent rail system of transportation between the mid-1950s and the 1970s, which functioned as a safer, cheaper, and more effective way of delivering passengers, products, and services across the country and as a significant source of employment (Omishore, 2016). From the mid-1980s, when the Nigerian Railway Corporation was declared bankrupt, until very recently when it was resuscitated, little or no investments were made in the Nigerian rail sector until the inception of civilian administrations in 1999 when the rail sector received some serious attention. In both developed and developing countries, rail transportation has a strong foundation for social and industrial operations.

However, it looks that Nigeria and Nigerians cannot realise their ideal of having efficient rail transportation infrastructure (Omishore, 2016). The problems hindering the effective development of the Nigerian Railway system are a multitude, but the most important ones, as adduced by Sumaila A.F., (2013), are listed below:

- Technical problems such as tight curves, steep gradient, rail buckling with associated track/speed limits
- Poor communications
- Government interference with the management structure
- Lack of freedom to set tariffs
- Underfunding
- Falling rolling stock level
- Plummeting traffic levels (freight and passenger)
- Inflexible bureaucracy
- Volatile staff training

Despite recent efforts to repeal and re-enact the Nigerian Railway Corporation Act, some of the highlighted problems persist to date. However, a closer review of how the railway system was rejuvenated through legislation is pivotal in encapsulating the government's efforts so far. The nature, magnitude and dimensions of these problems, including their possible solutions, do not only feature prominently in official and research documents on Nigeria but are also placed on the front burner of major discourse on Nigeria. What has remained disturbing today is the continuing inability of the various solutions to effect significant improvement in the transport system. Instead, the situation appears to be getting worse (Sumaila, 2008).

It has been stated that the railway crisis in Nigeria has been aggravated by the lack of a clearly articulated policy for its development. This position is based on the widespread agreement that there is an imbalance in the rail transportation system between resource allocations to various modes, gross inadequacy of existing infrastructure, and a misalignment between the objectives of transport parastatals and operators and the material and organisational resources available to them (Levinus, 2020). These are undeniably significant challenges that a national policy should seek to confront and fix. As a result, it may be inferred that the Nigerian railway transportation system's chronic inefficiencies are due to policy inconsistencies, faults, and deficiencies, which have resulted in piecemeal and uncoordinated rail transportation program planning and implementation (Sumaila A.F., 2013).

Figure 1: Rail Line, Straight Lines Between Nodes, and Nodes(Okoye, Pongou and Yokossi, 2019)

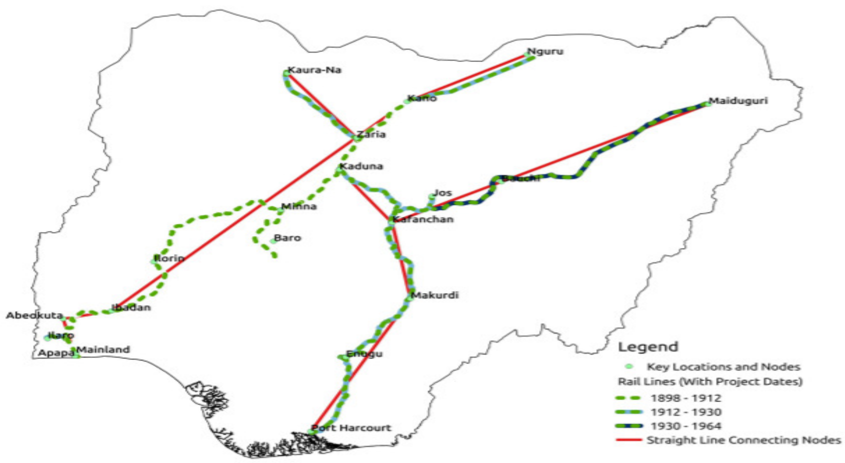


Figure 2: Rail Lines, Roads and Placebo Lines(Okoye, Pongou and Yokossi, 2019)

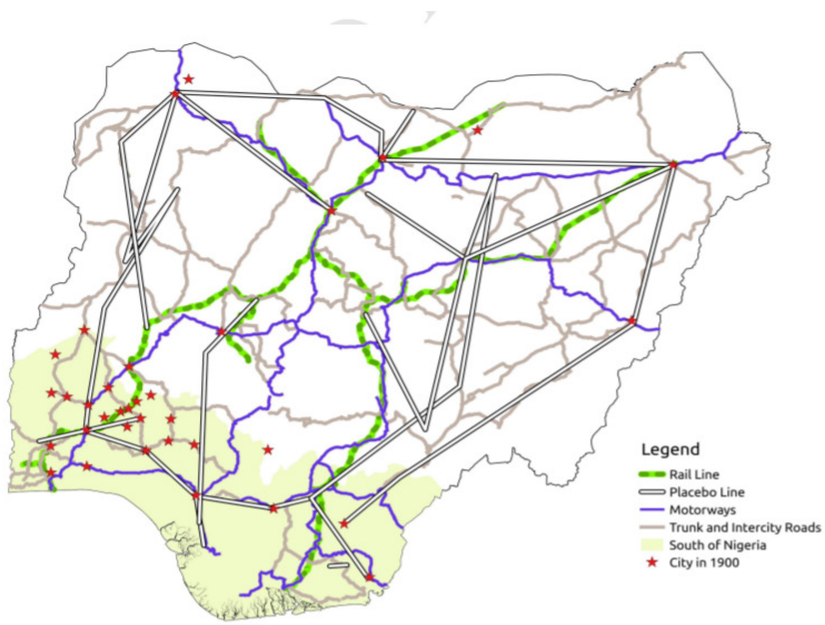


Table 1: History of Railway Construction in Nigeria(Manji Y., 2020)

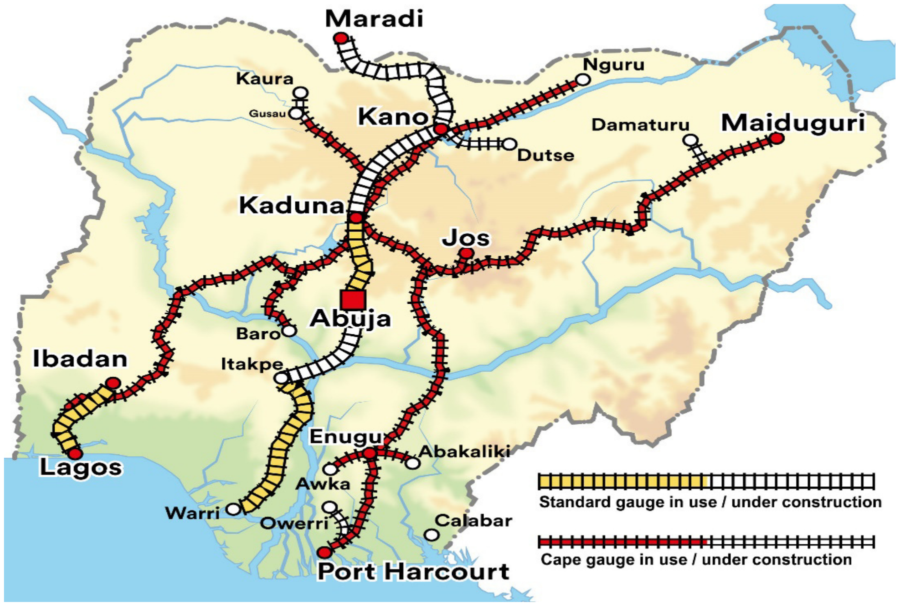
LINK	DATE	LENGTH (KM)	MOTIVATION
LAGOS - OTTA	1898	32	Administrative & Agricultural
OTTA - ABEOKUTA – IBADAN	1901	165	Administrative & Agricultural
IBADAN - ILORIN	1908	201	Administrative & Agricultural
ILORIN - JEBBA	1909	96	Administrative & Agricultural
ZARIA - JOS - BUKURU	1911	227	Mineral
JEBBA - ZUNGERU - MINNA	1912	233	Administrative & Agricultural
BARO – KANO	1912	573	Administrative & Agricultural
PORT HARCOURT - ENUGU	1916	243	Agricultural & Mineral
ENUGU - MAKURDI – JOS	1927	596	Agricultural & Mineral
KADUNA - KAFANCHAN	1927	201	Agricultural & Mineral
ZARIA - GUSAU - KAURA NAMODA	1929	232	Agricultural
KANO - NGURU	1930	229	Agricultural
IFO - ILARO - IDOGO	1930	39	Agricultural
JOS - MAIDUGURI	1964	645	Agricultural

1.3 Scope of the Study

The purpose of this paper is to illustrate the rail freight dynamics in Nigeria prior to railway liberalisation using complete commodity flow invoice data from 1977 to 1994. For major freight commodity types, the spatial distribution of domestic rail freight flows is presented. Using a web-based Geographical Information Systems (GIS) tool developed for this study, thematic maps are created to identify significant origin and destination stations, as well as rail corridors. Analyses of a similar nature are repeated for various commodity flow types as well as revenue earnings. Additionally, a city-based freight movement evaluation is conducted to investigate and establish a link between their rail (and maritime) freight and socioeconomic parameters. Additionally, the discussion section evaluates the Nigerian State Railways' international freight transport. The findings are expected to provide guidance to rail freight operators (both incumbent and newcomers), shippers and consignees, and policymakers as they prepare for and act on post-reform challenges and opportunities.

The primary contribution of this paper is to paint a picture of the rail freight sector dynamics in Nigeria as a whole prior to the liberalisation of Nigerian railways. The study has some limitations: as the railway reform process progresses, data belonging to private sector stakeholders are not readily accessible due to commercial concerns. Additionally, the study depicts the rail freight sector in a GIS environment, which is extremely difficult to do in a developing country like Nigeria without geocoded network and commodity flow data. This study was unable to accurately estimate national and international freight demand in Nigeria due to a lack of socioeconomic data for cities/regions in the country. However, significant characteristics of the rail freight sector and its evaluation in relation to the cities' GDP were identified, which can be used in future studies examining the consequences of this liberalisation in Nigeria.

Fig. 3. Nigerian Rail Freight network in association



2. Data and Methodology

Commodity flow data from the 17-year period (1977 to 1994) preceding Nigerian railway reform were analyzed, as these datasets were digitally recorded and made available. Earlier records (i.e., prior to 2004) were manually archived for general statistical purposes, and thus detailed data for earlier periods could not be retrieved, except for the basic yearly statistics published. It should be noted that the rail freight data in this study is derived primarily from invoices, which means that even a dozen tonnes load of the same product may appear in the records as a single entry, whereas there may be minimal quantities of the load based on the customer order specification. This is a significant limitation for the train-based analysis in this study (train-km, train-tonne). Additionally, the lack of additional information about the load's transportation (i.e., an exact date) precludes us from conducting an in-depth analysis based on monthly or daily movements.

Due to the absence of an algorithm (1959) embedded in the web tool, a web-based GIS-digital map with coordinates and railway connections is generated specifically for this study. This assumption was not anticipated to introduce significant ambiguity into the process, as the rail freight network is sparsely connected and typically generates a single path for the majority of O–D pairs. To facilitate the implementation of the internationally accepted standardised goods classification system (NST-2004), commodity types recorded in the dataset were reclassified into types (see Table 2).

Table 1: Standard good classification for transport statistics

TYPE	COMMODITY TYPE	TYPE	COMMODITY TYPE
0	Empty	9	Secondary raw materials
1	Products of agriculture, hunting, and forestry	10	Mail and parcels
2	Coal and lignite; peat; crudepetroleum	11	Machineryand equipment

3	Metal ores and other mining products	12	Transport equipment
4	Food products, beverages, and tobacco	13	Goods moved in the course of household
5	Textiles and textile products	14	Coke, refined petroleum products
6	Furniture; other manufactured goods	15	Wood and products of wood
7	Basic metals; fabricated metal products	16	Hides and skin
8	Chemical, chemical products	17	Cotton and groundnut

Numerous similar products with varying price codes were grouped together in a single category. For example, wheat, oats, and other agricultural products are grouped together under the "agricultural products" category, Type 1, and their tonne and revenue values are added. It should be noted that NST 2004 is an acronym for standardised goods classification for transport statistics. It is a statistical term for goods transported via four modes of transport (road, rail, inland waterways, and maritime) (Eurostat, 2019). The database that supported the GIS interface contained a variety of fields that enabled thematic mapping of various states of rail freight, including the following:

i) Produce rail commodity maps for any selected O–D pair and analysis period on a disaggregated and load type-specific basis.
ii) The calculation of Production (P) and Attraction (A) values was made possible by aggregating the loads of all the stations in a province.
iii) By assigning a selected load type(s) to any periodic analysis of the entire network, line densities for various railway corridors were generated. Additionally, it was possible to display the load on a rail freight corridor in this manner.
iv) Additional city-level aggregation via the calculation of total net weights (transported, produced, or attracted values denoted as TNW, PNW, and ANW, respectively).

The revenue-based analysis conducted in this paper is based on the invoices' "total revenue" values, which include revenue from other items (i.e., long-term parking revenues, container rental fees, and any penalties imposed on container transport). To present a more realistic picture and to mitigate currency-related inflation effects, revenue was calculated in USD using annual currency exchange rates (3.12 TL/USD for Nov1975–1994 as a mid-interval value).

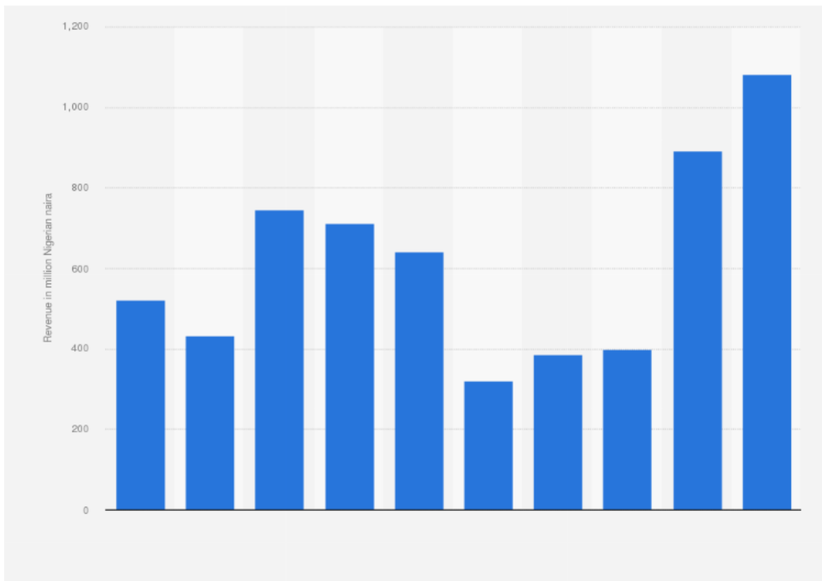
3. Findings and Discussions

Due to the fact that the analysis is performed at the freight station level, it is possible to depict the activity of freight stations in a thematic map based on the net cargo produced (origin) or attracted (destination). Additionally, by allocating demand to the shortest rail routes, railway line densities were generated, as illustrated in the composite map in Fig. 4, which includes four key indicators: rail freight production (PNW) and attraction (ANW) hotspots, network densities (Fig. 4), and generated Total Transport Revenue (Fig. 4).
We discover that certain sections of the railway network have a high rail freight density, while the remainder of the network is barely used. The corridor with the highest density is between the provinces of Nguru and Ibadan, as this axis is home to one of Nigeria's agricultural activities. Commodity-based

analysis requires data on production–attraction freight flows, which are typically gathered through historical quantity flow surveys or through real-time data provided by operator companies (Croce, Musolino, Rindone, & Vitetta, 2020). To be more transparent and precise about pricing and revenue details, the invoice data registration system uses a highly detailed commodity identification system (more than 250 categories).

From a revenue generation standpoint, the analyses indicate that metal ores and mining products accounted for the majority of rail freight movements, accounting for 571.90 million USD in revenue over a six-year period, while coal and lignite loads (Type 2) accounted for 217.89 million. Policymakers at the national and regional levels can foster a competitive environment that attracts private sector firms. Cities with high GDP data, in particular, should have little difficulty attracting railway freight operators. A word of caution should be issued to policymakers and regulators regarding a highly likely but undesirable process of adaptation and even possible failure of the incumbent company, as has occurred in some European countries.

Figure 4: Nigerian Freight Transport Revenue(Statista 2021)



More precisely, the incumbent state-owned company may be unable to compete effectively with the new private firms, resulting in the loss of loyal existing customers and critical rail corridors. This could result in job losses and employee dissatisfaction (those who have worked for the company for a long period of time in a different market environment with different priorities and mindset), which could result in labor unrest. On the plus side, if private and incumbent companies manage the early post-reform market conditions effectively and take appropriate measures, there may be an overall increase in market share, i.e., a modal shift from road to rail, as the competitive environment will offer efficient, reliable, and customer-tailored service and attract new customers with a variety of cargo types (Islam, Jackson, Zunder, & Burgess, 2015).

4. Conclusion and Recommendations

As foreseen in the reform process, the Nigerian rail freight sector is going through a reform process that allows private and incumbent companies to compete fully since 2004. In the absence of data for the post-reform period, this paper focuses on evaluating the sector just before the liberalisation using the commodity flow invoice data from 1977 to 1994. Geocoding of the data based on origin and destination station information (and a shortest path assignment procedure) using a web-based tool designed especially for this study enabled the determination of hotspots (in terms of rail freight production and attraction) as well as line densities for freight corridors. Furthermore, total transportation cost information in the invoice data- enabled determination of revenue based geographic distribution of different commodities in the rail network. As expected, the GIS-based analysis results show that the Nigerian rail network mostly serves bulk commodities such as metal ores, coal and lignite, and non-metallic products. However, the geographical distribution of these commodities shows unbalanced load dynamics in which a few cities had very high rail freight activity for specific commodities due to production or attraction. Rail network demand remains almost constant for different categories over the studied period, suggesting that it is not very sensitiveto socio-economic factors. In terms of bulk transport revenue production, rail system in Nigeria has the potential for the highest revenue contribution, with more than 40 million USD per year; with Lagos- Maiduguri, Ibadan-Nguru corridors carrying commodities with revenue potentials of more than 60 million USD annually.

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