# COMPARATIVE ANALYSIS OF THE MODES OF TRANSPORTATION OF PETROLEUM PRODUCTS OUT OF KADUNA REFINERY AND PETRO-CHEMICAL COMPANY, NIGERIA

**BY**

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## Declaration

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All borrowed ideas have been duly acknowledged by means of references and quotation marks.

_____ _____

Obafemi Thompson OBASANJO Date

## Certification

This thesis titled "Comparative Analysis of the modes of transportation of petroleum products out of Kaduna Refinery Petro-chemical Company, Nigeria" by Obasanjo, Obafemi Thompson meets the regulations governing the award of the degree of Master of Science in Transport Management of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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## Dedication

This thesis is dedicated to GOD who, through His infinite mercies, made it possible for my Dad and Mum – Pastor & Mrs. M. O. Obasanjo, to realize their dream of having an educated child and to all young ones out there, striving to be educated.

**Acknowledgment**

All I have, all I am, all I will ever be is released from above; therefore, I am indebted to God for His numerous gifts, guidance, provisions and sustenance towards me. Thank you, Lord.

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## Abstract

Issues such as time, safety, cost, reliability, speed and capabilities need to be considered for a transport system to be effective and efficient. Transport cost goes a long way to determine the price at which the end-user will purchase a product. This study seeks to compare the cost, time, constraints and the pattern of flow transporting petroleum products by three different modes of transport out of Kaduna refinery to selected locations in northern Nigeria. Data used are from both primary and secondary sources. Information was obtained from truck drivers using systematic sampling techniques while interview was used to source for information from Pipeline and Product Marketing Company officials and Nigerian Railway Corporation. For the truck drivers, every seventh driver awaiting loading at the refinery were interviewed for ten (10) days. In all, 182 respondents were successfully interviewed on issues such as constraints associated with the transportation of petroleum products, time and cost of transporting petroleum products by different modes and the frequency of trips. Secondary sources include information from NRC and PPMC. The data obtained were analyzed using both inferential and descriptive statistics. Proportional flow map was used to show the distribution pattern of flows, the result revealed that Kano recorded the highest quantity of tankers in-flow for the delivery of petroleum products. Using K-W test, the study reveals that the major constraints confronting tanker drivers in conveying petroleum products to the selected locations is delay at police and military check points (mean= 1.72), followed by mechanical problems (mean=2.17). Furthermore, the correlation matrix of the trucking problem result reveals that five pairs of the variables were inter-related; these variables are bad roads, off-loading, delay at police and military check points, short deliveries, mechanical problems and theft/robbery. The student t-test also shows that distance, cost and temporal variation were significant at 0.05 confidence level using Student-t test. Also, Student-t test was conducted for cost and time of transporting petroleum products and it revealed that there is a significant difference in the cost and time of transporting petroleum products by rail, road and pipeline. It shows that the adoption of pipeline transport as the major means of transporting petroleum products could potentially save up 95 percent of the haulage costs while rail transport could save up to 40 percent. For instance, the combination of road-pipeline costs shows a t-test value of 4.902, p. $<0.004$, while rail-pipeline shows a t-test value of 4.744, p.$<0.005$ and road-rail indicates a t-test value of 3.815, p. $<0.012$, at 5 degrees of freedom and at 0.05 level of significance respectively, in that the compared mean's *t-test* is statistically significant, t value is 3.382, p.$<0.020$ for road – rail time. The time difference is also significant for rail-pipeline transport with t-value 5.491, p.$<0.003$ and road-rail transport with t-value 5.358, p$<0.003$, at 5 degree of freedom and at 0.05 level of confidence. Cumulatively, this shows that pipeline transport is the most cost-effective mode of transport. It is on the basis of these findings that the study recommend an effective implementation and improvement on the usage of pipeline transport as the major mode of transporting petroleum products.

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# CHAPTER ONE: INTRODUCTION

## 1.1 Background to the study

Transportation is an important aspect in the distribution of petroleum products as the production centers are usually far from consuming areas. A large proportion of the world's refineries are located far from the market. The fluidity of most of the petroleum products makes it amendable to transportation by any agency capable of removing a liquid from one place to another by trucks, railroads, ships and pipeline (Ikporukpo, 1977).

According to Coyle *et al* (2003), transport is like a physical tread that connects firms that are geographically dispersed. The transportation link allows the flow of goods between the various fixed points from the points of production to the points of consumption that are distinctly spatially separated. Ballou (2004) on noted further that inexpensive, high quality transportation also encourages an indirect form of competition by making goods available to a market that normally could not withstand the high cost of transportation. This is an important issue, especially in determining the affordability of goods and services. In order to develop a good distribution network, the transport systems such as modes of transport, delivery operation and logistics, types of delivery operation and route scheduling are all important factors that need to be considered (Rushton *et al*, 2000). An efficient and effective logistics is a function of how well the transport system is structured, considering issues such as precision, just-in-time, frequency, distance and time (Jespersen and Nielsen, 2004). Therefore, transportation decisions such as modal choice decisions are strategically important for effective logistics and supply chain operation.

In transporting goods, we have different modes such as road, rail, air, water and pipeline transport as options. However, each mode has its relative advantages and weaknesses with reference to carrying capacity and distance. Road transport is flexible, easy to operate and allows for easy break of bulk than most other modes of transport. Rail transport on the other hand, is comparatively cheap, relatively safer in terms of accident occurrence, more expensive than roads to construct but cheaper to maintain and has a better carrying capacity when compared with road transport. Pipeline can easily be laid through difficult terrains, and once laid, it does not usually require much maintenance, which makes the supply of products through it more reliable, faster, steady and has capacity for door to door service (Emielu, 2000).

The various modes of transporting petroleum products complement each other on numerous occasions, although in some cases they stand in competition against each other. The two main modes that are used for long distance transportation of petroleum are pipeline and water transport, while rail and road may become highly advantageous when relatively short distances are involved. Road transport forms the major linkage between the depots and the bulk consumers and retails outlets (petrol/gas stations and warehouse) to the petty consumers. The cost per unit of transporting the products by road depends both on the road tanker vehicles in use and the marketers (Oyesiku and Obadimeji, 1998).

Crude petroleum is the most significant mineral resource in Nigeria that is crucial to the Nigeria's economy. It accounts for over 95 percent of export earnings and about 85 percent of government revenues than any other mineral or product and the country's oil reserves as at 2010 is 31 billion barrels (Economic Confidence, 2012), while gas reserves were 260 trillion standard cubic feet and the country oil production is 2.5 million barrels per day (NNPC, 2012). Before 1986, hardly any petroleum product was imported as the local refineries were functioning

properly and were regularly maintained. However, from 1990, the percentage share of imported petroleum products began to rise. The importation of Premium Motor Spirit and Dual Purpose Kerosene rose from 11.4 percent and 13.30 percent respectively, especially in 1990 to 82 percent and 64.87 percent respectively in 2000. According to Nigerian National Petroleum Corporation (NNPC), the refineries could produce 18 million litres of PMS per day at full capacity, while consumption is 30 million litres (TELL Nigeria, 2005). Consequently the balance of 12 million has to be imported (OPEC, 2006).

In Nigeria, refined petroleum products are supposed to be transported from the three refineries located in Kaduna, Portharcourt and Warri through a network of pipelines, coastal (marine) vessels, road trucks and rail wagons to the 21 regional storage/distribution depots, spread across the country. It is from these depots that the marketing companies are supposed to obtain their supplies. These distribution depots, with a total capacity of 1,422,000 cubic metres, and the pipeline transportation system are managed by NNPC through its subsidiary, the Pipelines and Products Marketing Company (PPMC). The depots are linked to the refineries and port terminals by a 3,949km network of pipelines for the transportation of refined products in five systems (Mbendi, 2011).

NNPC is supplied through imports and locally refined products by both the major and the independent marketers. The major marketers account for 70% of products distributed in 2008, according to data from the Nigerian National Petroleum Corporation (NNPC, 2008). They include the state-owned NNPC retail, multinational petroleum marketing companies such as Total, Mobil and Chevron, and the largest indigenous operators, African Petroleum (AP), Oando and Conoil. The independent marketers comprise a large number of indigenous operators (Olubunmi, *et al* 2010).

Domestic supply is obtained from the nations' three refineries, Warri (WRPC), Kaduna (KRPC), and Port-Harcourt (PHRC), which process crude oil allocated by the Federal government. Due to management problem, the local refineries continue to operate well below their estimated capacity. In 2008, the average capacity utilization of all three refineries was 22% with an average of 25% over the last 5 years (Trade Invest Nigeria, 2011). Prior to the establishment of the first phase of pipelines facility in Nigeria 31 years ago, distribution of petrol fuel was a headache for the seven oil marketing companies and their distributors.

The petroleum marketing companies sourced products themselves, transport and distribute them using their own distribution and retail outlets. There are now in place about 3000km of petroleum products pipelines network, 21 storage depots, 9 Liquefied Petroleum Gas (LPG) depots and associated facilities that have been added to facilitate production, storage, distribution and marketing of petroleum products to meet growing demand. However, pipeline distribution has been suffering persistent disruption in the decade. About 2,258 incidences of pipelines vandalization was reported in 2005 by NNPC as against 1121 cases in 2000. In 2005, NNPC recorded a loss of over 650,000 metric tons of products to theft through pipelines vandalization and explained that it was unsafe to pump products through pipelines (Ntiense, 2006).

In Nigeria, about 80% of petroleum movements are done on the road and there has been a steady growth in number of road tanker vehicles. There is an estimate of 5,000 tankers involved in wet cargo haulage, to move about 150 million litres of fuel and 2,500 trailers in dry cargoes plying Nigeria roads daily. However, bad roads, poor road networks and also various hindrances such as delays at police and customs check points obstructs an effective and efficient logistics (Olagunju, 2011). Since the collapse of the rail system in Nigeria, road haulage has assumed a

wider dimension and has become the most utilized way of intercity movement of goods and services, which has also led to the inflation of transport cost.

## 1.2 Statement of the Research Problem

Refined petroleum products may begin the journey from the refinery to consumers via a pipeline system, ships, rail cars/wagons, and trucks and may be stored in distribution terminals before reaching the final destination, the consumer's tank (Attwood, 1992). However, in a country like Nigeria, the distribution of petroleum products comes with its peculiar challenges (Maitumo, 1999) as it is only the road mode that has come to be used for transporting refined petroleum products to the inland areas of the country in the last seventeen years.

Road transportation is the dominant mode of transportation in Nigeria. The restrictive nature of the water ways, coupled with the near collapse of the rail system, and the high cost of air travels have further exerted a lot of pressure on the road as over 70 percent of the total movements in the country are made by road. In fact, about 80% of the freight movements are done on the road (Olagunju, 2011). In Nigeria, there has been a steady growth in the number of heavy goods vehicles. We have an average of about 5,000 tankers involved in wet cargo haulage, to move about 150 million litres of fuel and 2,500 trailers in dry cargoes plying Nigeria roads daily (Olagunju, 2011). However, in Nigeria, bad roads, poor road networks and also various hindrances such as delays at police and customs check points obstructs an effective and efficient logistics.

As noted by Pedersen (2003), trucks seldom drive more than 25,000 km per annum due to the nature of the poor state of African road transport network. Road infrastructures are large consumers of space with the lowest level of physical constraints among transportation modes.

However, environmental constrains are significant in road construction. Due to the poor road infrastructure in Nigeria, all vehicles using the road transport systems have high maintenance costs (Olagunju, 2011).

Pipeline transportation has been well known for its limited offer of a range of services and capabilities (Ballou, 2004). But in the area of oil and gas transportation, it has proved to be an efficient means of transportation. Milidiu *et al* (2004) see the pipeline as a unique form of transport having a stationary carrier but moving cargos which in other modes of transport is the reverse. He further stresses that the management of pipelines is a complex task which raises important issues such as logistics and planning, maintenance and environmental safety.

According to Ballou (2004), pipeline service is the most dependable of all modes of transport because there are few interruptions to cause transit time variability as weather is not a significant factor and the pumping equipments are highly reliable. He also observed that product loss and damage for pipeline is low. However, it must also be noted that pipelines are frequently subjected to vandalization, especially within the Niger Delta region of Nigeria. Overall, pipelines are seen as an environmentally friendly means of transporting petroleum products. In spite of this advantage, pipelines have not been effective in transporting petroleum products in Nigeria.

An econometric analysis of domestic transportation of refined petroleum products in Nigeria by Nnadi and Cmilt (2007), examined the time refined products are transported domestically by road, rail, pipeline and waterway with the objective of determining which mode is more important in domestic carriage of white products since 2000. They concluded that the three modes (rail, road and pipeline) are basically of equal importance in their contributions to domestic conveyance of white products such as petroleum, kerosene and gas. Based on this

finding, the three mode of transportation may be said to be important but the study was silent on which among these three modes is most cost-effective?

Abdulmalik and Omokoghio (2009) revealed that petroleum products distribution by road is faced with short deliveries on a daily basis. In the distribution process, petroleum products are entrusted to the transporter and driver until the point of discharge at the dealers' premises. It is usually within this stage of the supply chain that short deliveries are experienced, where the quantity loaded is less than what is recorded at the discharge point. It has become a perennial problem in the industry to see short deliveries on a daily basis.

As is the case elsewhere, for instance, the United States of America, the pipeline is by far the most important mode of domestic transportation of both crude and refined petroleum products. According to the American Association of Oil pipelines (AOPL, 1998), of a total oil transport of 6,400 billion board miles (BBM), rail account for 2%, trucks 3%, water carriers 27% and pipelines 68%. The distribution is attributed to comparative cost economics of each mode. AOPL states that oil pipeline shipments account for more than 17% of the total freight moved nationally in the US but less than 2% of the national freight cost. To further highlight the advantages of the pipeline in domestic oil transportation, it is estimated that if each truck holds 200 barrels and can travel 500 miles a day, it would take a fleet of 3000 trucks, with a truck arriving and unloading every 2 minute, to replace a 150,000 barrel per day, 1000 mile pipeline (Tyndall, *et al,* 1998).

Nigeria has Africa's largest network of pipelines for refined petroleum products with a total length of 3,949 kilometers. While some of the pipelines are underwater, others are on or under the ground. Most lines are multi-product in transportation and are all under the management of the Pipelines and Products Marketing Company (PPMC), a subsidiary of the

Nigeria National Petroleum Corporation (NNPC) (Dacon Associates, 2005). In spite of the advantages of pipelines, road transportation remains the most patronized mode for petroleum haulage in Nigeria.

The significance of road haulage in this respect is what gave rise to zerorisation. The zerorisation principle, according to Mesaf Management Services (2002), was adopted to ensure that positive and negative transportation cost differentials will zero out to ensure the maintenance of a uniform pricing mechanism for pump prices nationwide. The study of Nnadi (2006) which set out to determine the mode that was more significant in the domestic transportation of white products in Nigeria revealed that road transportation of petroleum products was associated with problems such as short deliveries, road traffic accidents, lives and property destruction, diversion of products, delay of tankers as a result of traffic, bad road and non-chalant attitudes by some tanker drivers.

Previous studies tended to focus more on econometric analysis of domestic transportation of refined products by modes of transport, the constraints of petroleum haulage, supply of petroleum products and the significant mode in the domestic transportation of white products in Nigeria. It can be deduced that much academic attention had not been accorded to the most cost-effective mode of transporting petroleum products. Specifically, no empirical work carried out on transportation of petroleum products in Nigeria is dedicated to cost-effectiveness of petroleum haulage by modes of transportation in northern Nigeria. It is this gap in knowledge about cost-effectiveness of petroleum products haulage by modes of transport such as rail, road and pipeline that this study intends to fill.

## 1.3 Research Questions

This study attempts to seek answers to the following research questions arising from the problem focus of the study:

(i) What is the nature of the spatial flow pattern of distribution of petroleum products to selected locations by road, rail and pipelines in northern Nigeria?

(ii) What are the constraints associated with the transportation of petroleum products by road, rail and pipelines from Kaduna refinery to selected locations?

(iii) What is the cost effectiveness of petroleum products haulage by various modes - road, rail and pipelines?

(iv) What is the relative impact of distance on the determination of fare of petroleum product transportation?

## 1.4 Study Aim and Objectives

The aim of the study is to comparatively analysis the modes of transportation of petroleum products out of Kaduna Refinery and Petro-chemical Company by road, rail and pipelines. The specific objectives of the study are to:

(i) Highlight the spatial flow pattern of petroleum products distribution to selected destination towns from Kaduna refinery.

(ii) Examine the constraints associated with transporting petroleum products by road, rail and pipelines from Kaduna refinery.

(iii) Examine a comparative advantage of transport cost of petroleum products haulage by different modes of transport - road (trucks), rail and pipelines.

(iv) Examine the relative impact of distance on the determination of fare of petroleum product transportation.

## 1.5 Scope of the Study

The main focus of this study was to compare the level of efficiency, cost and time of moving petroleum products by rail, road and pipeline from Kaduna refinery to destinations such as Zaria, Kafanchan, Kano, Gusau, Kaura Namoda, Nguru, Bauchi, Funtua, Jos and Minna, which serves as the market. The selection of these locations was based on the availability of functional rail tracks, road network as well as the presence of pipelines. The specific petroleum products considered in this study are Premium Motor Spirit (PMS), Automotive Gas Oil or diesel (AGO), and Dual Purpose Kerosene/House Hold Kerosene (DPK/HHK). The issues addressed in the study are cost per km ton; timeliness of delivery, and constraints associated with petroleum products haulage by rail, road and pipeline. Figure 1.1 shows the road, railway and pipeline networks to the selected locations.

## 1.6 Significance and Justification of the study

The Significance of this study is that it shows that Nigeria uses the least cost-effective mode to transport petroleum products across the country. It is also significant to note that the two most cost-effective modes for long distance haulage of petroleum products in Nigeria have been neglected and left to rot. The study further shows that the nation stands to gain significantly by ensuring that the network of pipelines and depots are made to work and the railway is resusticated. The study is an eye-opener to policy makers and should make them

appreciate the need to up-grade the nations' transport infrastructure - rail, road, water and pipeline so that the country can take advantage of an integrated multimodal transport system.

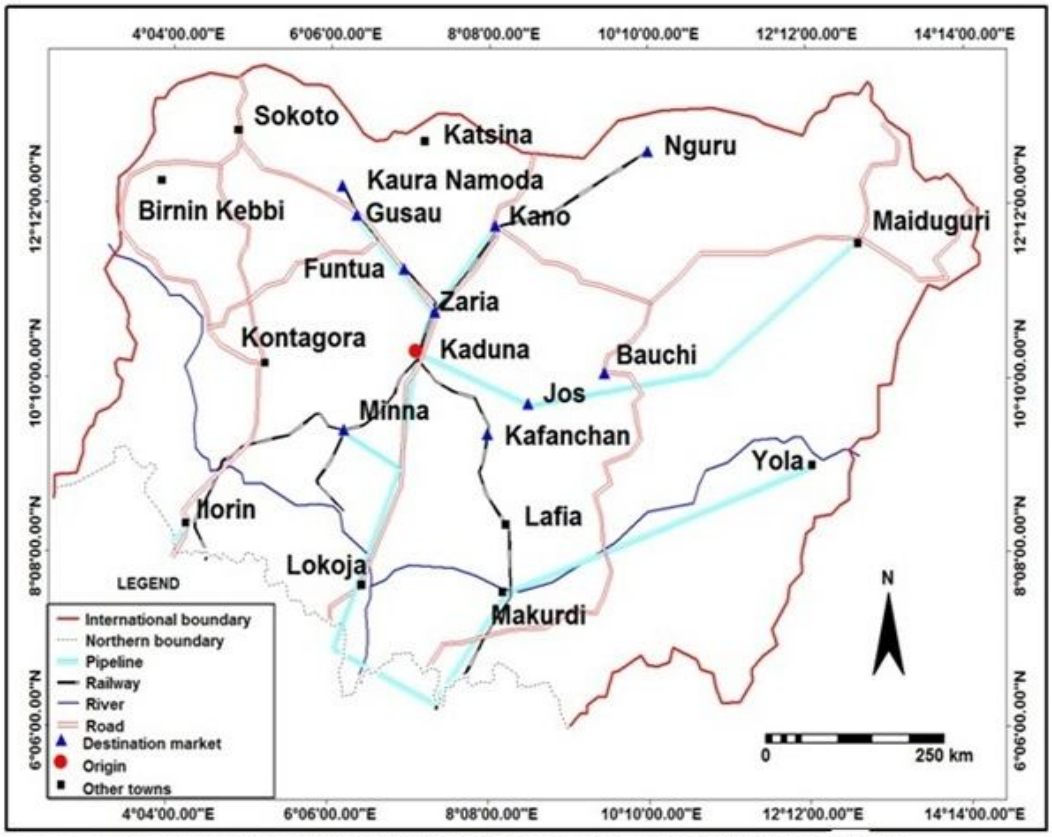



FIG. 1.1 : NETWORKS OF ROADS, RAILWAY AND PIPELINES IN NORTHERN NIGERIA

Source : Adapted and Modified from Julius Berger Road Map of Nigeria, 2000.

## 1.7 Hypothesis

$H_o$- There is no significant variation in the transportation cost and time per mode of transport in the transportation of petroleum products from refinery to final destination with relative distance.

$H_1$- There is significant variation in the transportation cost and time per mode of transport in the transportation of petroleum products from refinery to final destination with relative distance.

# CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

## 2.1 Introduction

Transportation concerns the movement of products from a source such as a plant, factory, or work-shop to a destination such as a warehouse, customer, or retail store. Transportation may take place by air, water, rail, road, pipeline, or cable routes, using planes, boats, trains, trucks, and telecommunications equipment as the means of transportation. The goal for any business owner is to minimize transportation costs while also meeting the demand for its products. Transportation costs generally depend upon the distance between the source and the destination, the means of transportation chosen, and the size and quantity of the product to be moved. In many cases, there are several sources and many destinations for the same product, which adds a significant level of complexity to the problem of minimizing transportation costs (Hoch, 1998).

Petroleum products are useful materials derived from crude oil (petroleum) as it is processed in oil refineries. According to crude oil composition and demand, refineries can produce different shares of petroleum products. The largest share of oil products is used as energy carriers: various grades of fuel oil and gasoline. These energy-carrying fuels include or can be blended to give gasoline, jet fuel, diesel fuel, heating oil, and heavier fuel oils. Heavier (less volatile) fractions can also be used to produce asphalt, tar, paraffin wax, lubricating and other heavy oils. Refineries also produce other chemicals, some of which are used in chemical processes to produce plastics and other useful materials. Since petroleum often contains a couple of percent sulfur, sulfur is also often produced as a petroleum product. Hydrogen and carbon in the form of petroleum coke may also be produced as petroleum products. The hydrogen produced is often used as an intermediate product for other oil refinery processes such as

hydrogen catalytic cracking (hydrocracking) and hydrodesulfurization. From the above conception petroleum and its bye products may include the following: Premium motor spirit (PMS OR PETROL), Automotive Gas Oil (AGO or Diesel), Household Kerosene (HHK), Aviation Turbine Kerosene (ATK or jet-Al), Industry Fuel, High pour Fuel Oil (HPFO), Low pour Fuel Oil (LPFO), Liquefied petroleum Gas (LPG), Bitumen and Base oil (Ehinomen et al, 2012).

In this chapter we examine the conceptual framework that is relevant to the subject matter of the study which is the Ullman's theory of spatial interaction and haulage cost gradient; give literature review, characteristics of an efficient transport system, characteristics of haulage transport modes, strategies of transport coordination, criteria for section of the best transportation mode, transport development in Nigeria, petroleum product transportation in Nigeria and haulage of petroleum products in Nigeria.

## 2.2 Conceptual framework

The basic theory relevant to this study is Ullman's theory of spatial interaction. Spatial interaction is a dynamic flow process from one location to another. It is a general concept that may refer to the movement of human beings such as intra-urban commuters or intercontinental migrants but may also refer to traffic of goods such as raw materials or to flows of intangibles such as information. In Ullman's conception there are three bases for spatial interaction these are: complementarity, transferability, and intervening opportunity (Ullman, 1980).

Complementarity refers to the presence of a demand at one location and a supply at another without which there is no economic rationale for any movement. A refinery is a place

with a supply for petroleum product while filing stations and consumers demand for the petroleum products. To adapt a metaphor from physics, complementarity is like a potential gradient with goods and people flowing from higher energy state where they are in surplus to a lower energy state, where they are in deficit (Ullman and Harold, 1954). The complementary surplus-deficit relationship is commodity-specific, and if the deficit is precisely specified, the direction and distance of movement will depend on the location where there is a surplus of just that kind of good. Complementary relationships may be the impetus for interaction between distant regions such as the flow of petroleum over thousands of miles from the point to the other and within regions such as the flow of shoppers from residential neighborhoods to small convenience stores over a distance of less than a mile or two (Ullman, 1980). The various modes of transport can complement each other in the movement and distribution of petroleum products from origin to destination, although in some cases they stand in competition against each other. This means that demand for and supply of transport services must exist.

Transferability refers to the cost of overcoming distance measured in real economic terms of either time or travel cost. The cost of overcoming distance is known as the "friction of distance." If the friction of distance is too great, interaction will not occur in spite of a complementary supply-demand relationship. Friction of distance depends on prevailing transportation technology and the price of energy. Daily commuter flows, for example, are always subject to a travel time constraint with two hours being a typical maximum for the one-way daily journey to work. High-value, liquid bulk goods such as petroleum products are imminently transferable and exported on a global scale while heavy, low-value goods such as concrete blocks are usually used very close to where they are produced. With the usage of various modes of transport, petroleum products are transferable from one mode to the other. For

example, pipeline transport can be used from the refinery to the nearest depot, from where the petroleum products will be transferred to either rail or road transport based on the relative distance as the cased may be, which will eventually aid easy distribution of the products and reduce cost of transportation (Ullman, 1980). The petroleum products in question must be capable of being moved so as to be able to overcome the distance friction.

Intervening opportunity is the third basis for interaction, although, it is typically considered as the reason for a lack of interaction between two complementary locations. Complementarity will only generate a flow if there is no intervening, or closer, location. The flow of goods that would otherwise occur between two complementary; locations may be diverted to a third location if it represents an intervening opportunity: a closer complementary alternative with a cheaper overall cost of transportation. However, Ullman (1954) noted that the trade diverting effect of an intervening opportunity could eventually facilitate interaction between more distant complementary locations. For example, the nearest (intervening) source of petroleum products would justify construction of a refinery from the raw material source and when it was produced, the pipeline would be extended to the next intervening opportunity and so on until it ultimately reached a more distant complementary location. Flows to the more distant complementary location might never have been established had the transportation infrastructure not been constructed in a series of incremental extensions to a series of intervening opportunities (Ullman, 1956). For destinations where there is no interaction between modes of transport, the intervening opportunity will be the next available mode of transport to distribute the product. This implies that there can be an intervening circumstance between the demand and supply locations.

Assuming that the filing stations (marketer's destination) gets their supply of petroleum products from the refinery, and petroleum product depots happened to be located in-between filing stations (marketer's destination) and the refinery, and also supplying exactly the same type of product as the refinery and at a shorter distance, which reduce cost. Then the petroleum product depot is in an intervening opportunity to the refinery. Therefore, these three aspects or components of transport must exist for a meaningful interaction to take place. This indicates that the services of the refinery to the filing stations (marketer's destination) should not reflect any monopolistic tendency if the intervening opportunity of the depots to render services to the filing stations (marketer's destination) (in place of the refinery) must occur at a particular point in time. The intervention of the depots would therefore reduce cost and also cover for the distance in the movement of goods and services. It also reflects the attribute of urgency of needs in the interaction and transaction of services between the filing stations (marketer's destination) and the refinery.

Important forms of spatial interaction such as traffic flows and migration may be predicted and explained based on an analogy with Newton's model of the gravitational attraction between celestial bodies. Assuming that there is no intervening opportunity, the degree of complementarity between any two regions is proportional to the product of the populations of the origin and destination regions and inversely proportional to the distance between them, representing transferability. Thus the level of spatial interaction may be specified as:

$$T_{ij} = k\frac{P_i P_j}{d_{ij}^{\delta}}$$

where $T_{ij}$ is the spatial interaction between origin $i$ and destination $j$, $P_i$ and $P_j$ are their respective

populations, $d_{ij}$ is the distance between them, and $b$ is an exponent representing the interaction retarding effect of the friction of distance which depends on transportation technology. To calibrate this simple model, a constant, $k$, is introduced to account for scale differences (Haynes and Fotheringham, 1984).

### 2.2.1 Haulage cost gradients

Virtually every kind of transfer entails some operation at the point of origin prior to actual movement and also further operation at the destination point. The cost of these "terminal" processes ordinarily does not depend on the distance to be travelled, whereas the costs of actual movement ordinarily do, because of these terminal costs, there is relationship between route distance and the total costs of transportation. Transfer costs are characteristically less than proportional to distance, and the average transfer cost per mile decreases as the length of haul increases. The greater the distance, the more likely it is that there will be alternative providers of mode of transport.

Each mode of transfer has its own cost and service characteristics and is more efficient than other modes for some classes of service and less efficient for other classes (Hoover, 1975). The cost gradients of water, rail and road transport of the same commodity is conceptualized as shown in Figure 2.1.

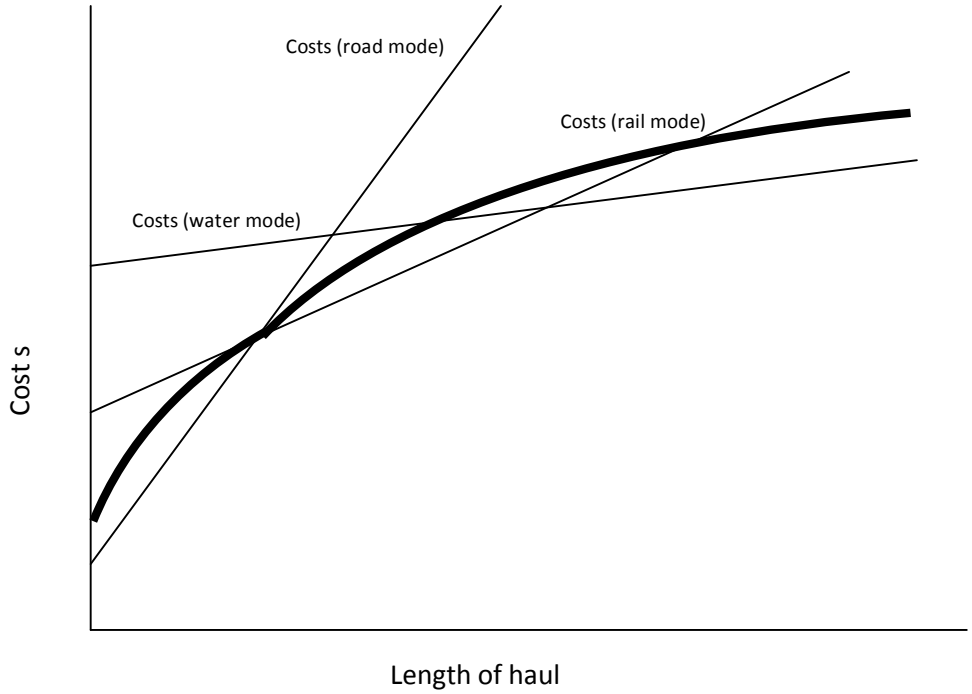



**Figure 2.1 Haulage cost gradient of road, rail and water transport' modes**
**Source: Adapted from Hoover (1975) haulage cost gradient**

The gradient of transfer rates with respect to distance is made much more curved than the single-mode transfer cost gradient. The marginal haulage cost tends to fall with increasing distance for water and rail than for roads due to cost of operation, construction and maintenance of road transport that is usually high (Hoover, 1975). Although it is not shown in Figure 2.1, the cost gradient of pipeline mode for long distance haulage should be flatter than that of rail and road over the same distance because of the lower construction, operation and maintenance cost of a pipeline network.

The concept of multimodal transport is predicated on the fact that each of the modes should be connected and integrated so that economic performance of the transport chain can be realized (Ubogu, 2010). Figure 2.2 shows how the varying proportions of types of cost and rate of increase with distance for different modes would affect their competitiveness. According to Bradfort and Kent (1979) where two modes of transport compete over the same route, there is likely to be strong competition in rates offered. Consequently, the various transport modes will

all have different transport cost curves as each mode tends to offer price advantages over different length of haul. In Figure 2.2 road haulage offers clear advantage between O and X, rail between X and Y and water beyond Y, while pipeline offers clear advantage from O and beyond.

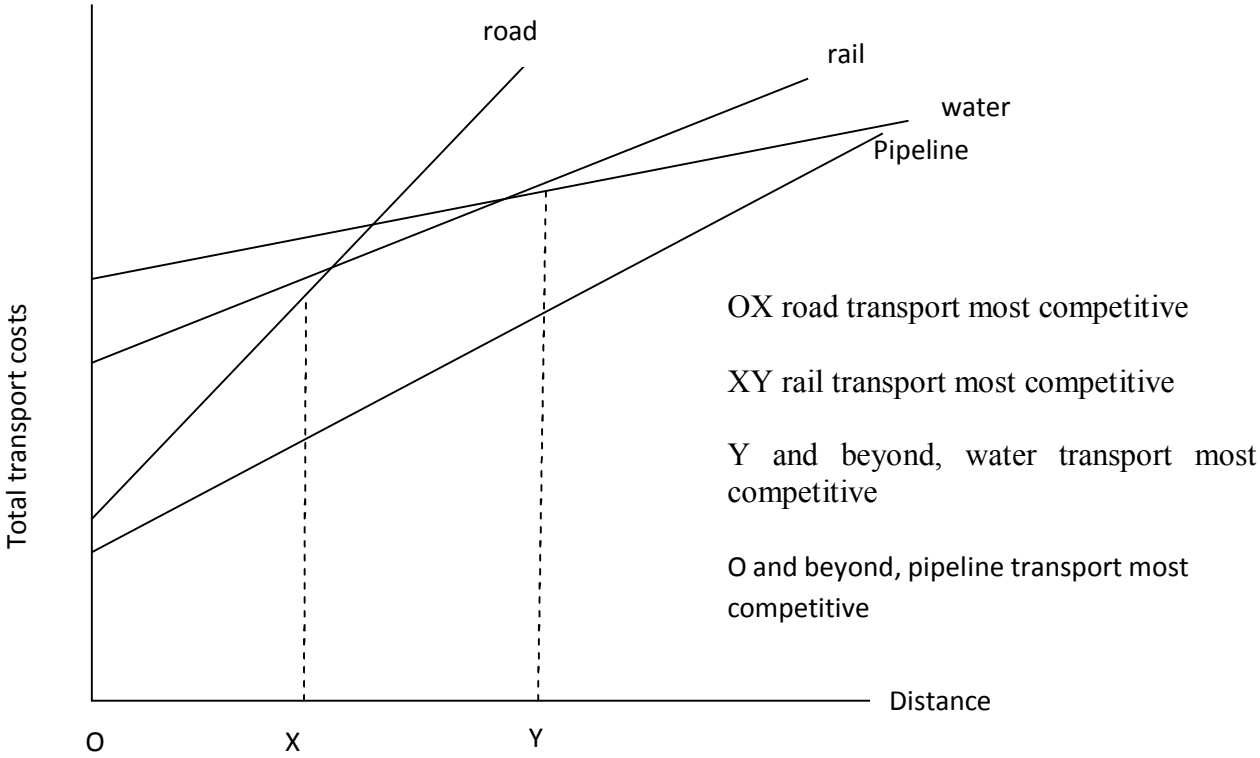



**Fig 2.2: Transport Costs of four transport modes**
**Source: After Bradford and Kent, 1979.**

This generalized transport cost curve show the wisdom in a nation developing an integrated multi-model transport system in order to enjoy to the full the advantage of each mode.

## 2.3 LITERATURE REVIEW

### 2.3.1 Characteristics of an efficient transport system

Capaciousness, flexibility, speed, timeliness, safety, comfort and affordability are the hallmark of an efficient transport system. So an efficient mode of transport ought to have the capacity to carry the quantities of products that are required to be moved. A transport mode that runs on time would reduce inventory levels and improve productivity and profits among its users. Underlying timeliness of a transport mode is the speed of movement of the mode. Some commodities have to be moved fast from origin to destinations as they have very short shelf life. Amongst such goods are perishable goods such as vegetables, flowers, livestock and organ (for transplant). Safety and comfort of products and human are important to transport users. Therefore, transport modes that are regarded as safe and comfortable would be highly patronized by shippers of goods and passengers. Flexibility of transport mode refers to the ease by which it can provide door-to-door services. For passengers and goods, the most preferred transport mode is the one that can bring goods to their shops and take them from where they live to as close as possible to their destinations. Finally transport modes must offer affordable services to enjoy high patronage (Anonymous, 2010).

### 2.3.2 Characteristics of major haulage transport mode

The different means of transportation have different characteristics and requirements that offer advantages and disadvantages depending on the particular circumstances of the operation. They also have different costs and capacity. But the decision about the type of transportation to be used is made based on other variables related to the needs identified and the concrete and available options. According to Douglas *et al* (1998) the needs identified include delivery

urgency, type and characteristics of the supplies to be transported, cargo, quantity, size, destination and distance all of which will determine the type of mode to be used and its cost. The options opened to a potential transport is also a function of available means of transportation, costs and resources available, access conditions to destination, route condition as well as weather conditions.

Basically there are six transportation modes. These are motorway, railway, seaway, airway, pipeline, and intermodal transportation.

(i) **Road transportation:** is one of the commonly used transportation modes. Road transportation is made mostly with trucks and articulated lorries. In motorway transportation, fixed costs are low, but variable costs are high. One of the advantages of motorway transportation is it flexibility to access nearly every point in the region or city. But, in road transportation, accident rates are high than the other transportation modes (Ozkan and Baslıgil, 2009). Road freight transport has advantages as cheaper investment funds, high accessibility, mobility and availability. Its disadvantages are low capacity, lower safety, and slow speed (Tseng *et al*., 2005). The excessive use of road transport also brings many problems, such as traffic congestion, pollution and traffic crashes. In the future, to improve the land transport in transport efficiency and reliability, a revolution of transport policies and management is required, e.g. pricing (Tseng *et al*., 2005). Trucking is a transportation service of semi-finished and finished products with an average length of freight haul 646 miles for less than truckload (LTL) and 274 miles for truckload (TL) (Ballou, 1999). The inherent advantages of trucking are its door to door service such that loading or unloading is required between origin and destination, as is often true of rail

and air modes; its frequency and availability of service; and its door to door speed and convenience (Ballou, 1999).

(ii) **Rail transport**: As regards railway transportation, goods that have low value but bulky are carried. Fixed costs are high because of the installation and maintenance costs. On the other hand variable costs are low. Because the goods are transported with high volume, the costs per unit are low, so it is a safe transportation mode. Transportation with railway is fast and transportation time is not long. These are the disadvantages of this mode of transportation (Ozkan and Baslıgil, 2009). Railway transport has advantages like high carrying capacity, lower influence by weather conditions, and lower energy consumption while disadvantages as high cost of essential facilities, difficult and expensive maintenance, lack of elasticity of urgent demands, and time consumption in organizing railway carriages (Tseng *et al*., 2005). Rail service exists in two legal forms, common carrier or privately owned (Ballou, 1999). A common carrier sells its transportation service to all shippers and is guided by the economic and the safety regulations of the appropriate government agencies. In contrast, private carriers are owned by the shipper with the usual intent of serving only the owner. Because of the limited scope of the private carrier's operations, no economic regulation is needed. Virtually all rail movement is of the common carrier mode. Railroads offer a diversity of special services to the shipper, ranging from the movement of bulk commodities such as coal and grain to refrigerated products and new automobiles, which require special equipment. Other services included expedited service to guarantee arrival within a certain number of hours; various stop-off privileges, which permit partial loading and unloading between origin and destination

points; pickup and delivery; and diversion and reconsignment, which allows circuitous routing and changes in the final destination of a shipment while en route (Ballou, 1999).

(iii) **Pipeline transport:** The advantages of pipeline transport are high capacity, less effect by weather conditions, cheaper operation fee, and continuous conveyance; the disadvantages are expensive infrastructures, harder supervision, goods specialization, and regular maintenance needs (Tseng *et al*., 2005). The most economically feasible products to move by pipeline are crude oil and refined petroleum products. However, there is some experimentation with moving solid products suspended in a liquid or containing the solid products in cylinders that in turn move in a liquid. If these innovations prove to be economical, pipeline service could be greatly expanded. With regards to transit time, pipeline service is the most dependable of all modes, because there are few interruptions to cause transit time variability. Weather is not a significant factor, and pumping equipment is highly reliable. Also, the availability of pipeline capacity is limited only by the use that other shippers may be making of the facilities at the time capacity is desired (Ballou, 1999).

(iv) **Water transport:** Transport way is one where if anybody has the right equipment can sail anywhere without obstruction. In practice the sea is a highway which is in the main free but has some restrictions placed upon shipping movements. Shipping movements are influenced by the following factors: Physical environment of the ocean and Wind forces generated by the ocean, weather systems can build up very large wave and swell pattern resulting at best in slowing the ship speed over the ground, at worst, in damage to the ship, passenger, cargo or crew or in some cases, in

total loss of the vessel. The main operating strength of the shipping industry lies in capability of moving vast quantities of cargo in one ship on one voyage. For the user, this is the cheapest method of moving goods worldwide. However, the main drawback is the speed which at 360 nautical miles per day on average is very slow especially when it is realized that ship operates continuously without a break.

The necessary resources to pay for the ideal mode of transportation will not always be available; or access conditions to the area may not permit using a specific type of transportation even when available. Therefore, the challenge not only consists of determining the needs, but also the actual possibilities and alternatives. For each means of transportation planned, there should be a backup plan in case circumstances make it impossible to use it (Douglas *et al*, 1998). The various modes of transportation have its relative advantage; the road transport offers door-to-door services due to it flexibility and available, that is, it is easier to find road tankers and cars than any other vehicles. For rail transport, it has ability to carry more quantity than road tankers at a cheaper cost. The dependability of pipeline transport is higher than other modes, they are virtually unaffected by weather condition and rarely have mechanical failures with low rate of transportation costs and time. Waterways and pipelines are generally the cheapest way of moving bulk materials in large quantities; the road transport has advantages of flexibility and convenience in local and short-distance movement. Clearly, if we are considering a wide range of lengths of haul for some commodity, the lowest-cost mode for short hauls need not be the same as the lowest-cost mode for long hauls.

### 2.3.3 Strategies of transport coordination

Several strategies can be used to coordinate the various modes in a country. In many cases, more than one of these strategies may be combined in any given attempt at transport coordination. Ikporukpo and Filani (2000) have very well reviewed these strategies and identified the following:

(i) Rate regulation: Rate regulation involves the fixing of rates by an agency, in most cases a public one in order to ensure that operators in a given mode do not have an undue competitive advantage over operators in the other modes through unjustifiable fixing of rates. To realize this objective, two distinct approaches are adopted. First, is the rigid tariff system that involves a fixed and inflexible freight rate for the movement of a given product over a specified distance on a particular route. Secondly, is the forked system which denotes the fixing of maximum and minimum rates by the regulatory body. Thus, operators are free to fix their rates flexibly within the limits specified (Olanrewaju, 1983; Stanford Research Institute, 1961).

(ii) Quantity control: This implies the regulation of the number of operators or number of trucks each operator could own. Usually, this strategy is effected through restrictive licensing. The logic behind this approach is to disallow a mode from out-competing another mode by having a large stock of infrastructure.

(iii) Distance regulation: This is deliberately initiated to limit the distance over which a given mode could operate or as succinctly put by Ikporukpo and Filani (2000:31) "a determination of the routes to be operated or both". Strictly speaking, this entails restricting, for instance, road vehicles to operate beyond predetermined distance from their base. It could also mean prohibiting them from operating in some routes on

other not to compete with rail and pipeline. For this reason, the protected mode may be in a position to carry out transportation tasks it is best suited to do.

### 2.3.4 Criteria for selection of the best transportation mode

The user selects a service or a combination of services that provides the best balance between the quality of service offered and the cost of that service. The task of service choice selection is not as forbidding as it first appears because the circumstances surrounding a particular shipping situation often reduce the choice to only a few reasonable possibilities (Ballou, 1999). To aid in solving the problem of transportation service choice, transportation service may be viewed in terms of characteristics that are basic to all services: cost, travel time, safety, air pollution, energy consumption, noise, and accessibility. These factors seem to be the most important to decision makers.

Ballou (1999) suggested some criteria for the selection of the best transportation mode as (i) cost, (ii) travelling time, (iii) safety, (iv) air pollution, (v) energy consumption, (vi) noise and (vii) accessibility. The cost criterion is critical in transportation mode. The cost components are installation cost, fixed cost, variable cost, usage costs and maintenance costs affect cost criteria. Generally, companies want to transport maximum loads with minimum costs (Ozkan and Basligil, 2009). Therefore, the most-cost effective should be used to minimize cost.

The benefits most commonly considered in benefit-cost analysis of transportation are (i) travel time or delay reductions, (ii) vehicle cost savings, (iii) accident reductions, (iv) air Emission and greenhouse gas reductions, (v) parking costs savings from projects that reduce vehicle ownership and use. All of these benefits are actually reductions in the costs of transportation. Other effects are difficult to value but may still be considered in an analysis in

which they are considered critical to making the choice among alternatives are (i) equity and option value impacts that result from projects that increase transport system affordability and diversity, (ii) induced travel, including new trips and changes in mode, route, and time of travel, (iii) travel time reliability, (iv) noise effects, (v) construction disbenefits, (vi) habitat and water quality impacts, (vii) economic effects, and (viii) community impacts (Transportation economics magazine,2012).

### 2.3.5 Transport Development in Nigeria

Transport development enables man to harness existing and new resources and to lease labour and capital previously tied up in less productive enterprises or isolated by distance. Transport is as old as man and human civilization. Basically, human porterage, animal porterage, water, air, land are major means of mobility. This aspect reviewed the rail, road and pipeline development of Nigeria with key focus on northern Nigeria.

#### 2.3.5.1 Rail development

Railway system in Nigeria is operated by the Nigerian Railway Corporation. The Nigeria railway system comprises of a total of 3,505km of narrow gauge-single track, running from the north to the south of the country (MITI, 2002). About 1,788km of the rail network are on 1,600 sharp curves of between 4 to 10 degrees (Akpogomeh, 2002). The narrow track structure and steep gradient in many places of the entire system limit the maximum speed to about 65km/h (Adesanya, 1998).

The rail has featured in the Nigerian product distribution system since the Second World War during which period Kano airfield was supplied product by pipeline from the Kano Railway Station (Ikporukpo, 1977), it also played a significant role in the transportation of goods such as

cotton, grains and groundnut from the northern part of Nigeria to the Eastern and Western parts of Nigeria. By the 1970s, about 10% of gasoline distributed was by rail. It was however, restricted mainly to the movement of product between the main supply points and inland depots. In certain cases, it was used in supplying industrial establishments. Distances involved in each of these were considerable which made its use economical. A total of about 520 rail tank wagons were owned by the marketing companies that were in charge of products distribution prior to 1973 but its use then was rather restricted because of the requirement for terminal facilities. The turn-around period of tanker wagons was unduly long. Factories that did not own storage facilities used tanker wagons as temporary storage facilities, which thus aggravated the railway distribution problem (Ikporukpo, 1977, pg.78). The rail system has declined from its 1977 10% involvement in products distribution to a zero level in 1990 (Nnaji, 1996, pg 28).

**Table 2.1: Relative Percentage share of petroleum products movement by the modes (1979 -2011)**

| Modes | 1979 | 1980 | 1982 | 1984 | 1986 | 1988 | 1990 | 2011 |
|---|---|---|---|---|---|---|---|---|
| Rail | 10% | 7% | 3% | 2% | 3% | 1% | 0% | 0% |
| Road | 47% | 30% | 25% | 25% | 27% | 26% | 23% | 62% |
| Sea | 43% | 30% | 22% | 23% | 25% | 28% | 50% | 17% |
| Pipeline | 0% | 33% | 50% | 50% | 45% | 45% | 27% | 21% |
| Total | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

**Source: PPMC Various Annual Reports**

Despite the problems associated with rail transportation, it remains one of the cheapest means of transportation. However, the massive deterioration and lack of maintenance of the rail in Nigeria has not made it a viable alternative. The train still runs on a narrow gauge with the maximum speed of between 25km – 35km per hour. The system would require massive

injection of funds to upgrade its tracks to standard gauge and modernize the wagons and haulage facilities (NRC Special Committee Report, October, 2000).

#### 2.3.5.2 Road development

Nigeria has the largest road network in West Africa and the second largest south of the Sahara, with roughly 108,000 km of surfaced roads in 1990 (Ubogu, 2010). Roads are by far the dominant mode of transport in Nigeria. The highways in the country generally account for about 70% of the movement of goods and persons in the country (Akpoghomeh, 2002). This is largely attributed to the natural advantage provided by the existence of vast land mass in Nigeria, when compared with waterways, and perhaps the inadequate attention being given to the rail system (Adesanya, 1998).

In northern Nigeria, road transport has been the major means of transportation with trunk A, B and C roads. The trunk A (major highway) serves as a connecting network system from the refinery to other towns in the northern part of the country. However, they are poorly maintained and are often cited as a cause for the country's high rate of traffic fatalities and the high density of petroleum tankers on the road create adverse effect on the durability of roads.

#### 2.3.5.3 Pipeline development

Among the various modes of transport, pipeline was the last to emerge in Nigeria. This is obviously due to the fact that petroleum, which is the basis for the development of the system, was discovered only lately (Ikporukpo, 1995). The historical development of this mode of transport is thus similar to those in other countries, such as the USA, where the system was developed in the mid-19$^{th}$ century. The pipeline used northern Nigeria is the multi-products

pipelines to move products to designated depots such as petrol, kerosene, diesel and gas to serve the storage infrastructure which consist of 22 loading depots linked by pipelines of various diameters ranging from 6 to 18 inches, has combined installed capacity of 266890 (PMS), 676400 (DDK), 1007900 (AGO) and 74000 (ATK) $M_3$ tonnes (Nnadi, 2006).

The choice of pipeline system for moving crude oil is based on cost consideration. This cost factor is best illustrated by the comparison of the cost of constructing pipelines and that for roads and rail. Pipeline transport has been particularly attractive for the uninterrupted movement of petroleum products. The cheap cost of moving crude products, as an advantage, is only shared by pipeline with super tankers. Thus, the economies of scale are particularly evident in pipeline transport, for costs fall sharply with increasing capacities of pipes. The possibility of moving solids in suspension or in capsules and even unsuspended solids through pneumatic pressure has made pipeline transport more attractive. In spite of this, the traditional role of pipeline as the conveyance of petroleum products continues to predominate (Ikporukpo, 1995).

**2.3.5.4 Water transport**

This mode covers inland waterways and maritime transport. It is a mode that is important for the development of any nation. Its importance can be deduced from the volume of traffic it carries. There are about 12 major navigable rivers, which together with inter-coastal waterways from east to the west frontiers amount to about 3,000 kilometers of navigable waterways in Nigeria (Abubakar, 1996). The rivers among which include the Niger, Benue, Num, Cross River and coastal creeks, especially in the Niger Delta. These constitute one of the longest inland waterways in the world (Akpoghomeh, 2002). The potential of this natural resource for transportation purposes are considerable. Since water routes are in most cases natural, the

provision of a fixed infrastructure in an inland water transportation system involves, other things being equal, little or no monetary cost except where sophisticated terminal facilities are required (Ikporukpo, 1994). Unfortunately, the potential benefit offered by this transport mode have not been fully exploited in large towns and cities such as Lagos, Warri, Port Harcourt, Calabar, Lokoja and Makurdi.

The navigable stretches of the country's inland water system of Rivers Niger, Benue and the coastal sub-systems had hitherto played significant roles in freight haulage in Nigeria. Prior to independence, agricultural goods and minerals destined to the coastal seaports were transshipped from northern part of the country via the navigable sections of Rivers Nile and Benue. The river port of Baro played a significant role in this process of freight transport. Such goods were transported either by road or rail to Baro and then hauled by boats to the coastal ports for export. Similarly, import good were transported from the numerous seaports to the hinterland via the coastal sub-systems, River Nile and Benue for onward transportation to hinterland cities like Kaduna, Zaria, Kano, Minna, Sokoto and Katsina (Ubogu, 2010).

### 2.3.6 Petroleum product transportation in Nigeria

In the last two decades, petroleum industry has become of strategic importance in the Nigerian economy, accounting for as high as 78 percent of Gross Domestic Product and up to 90 percent of the country's total annual revenue and foreign exchange earnings (National Bureau of Statistics, 2008). Movement of products from depots to service stations numbering several thousand- where they are retailed to the final consumers all over the country involves the use of road as the mode of transportation and the products are moved by large trucks. Rail transport was the first mode that was used for the distribution of petroleum products in the early 1960s,

subsequently; road transport was then engaged in the distribution while pipeline was used lately. The state of the railway system gave rise to the usage of road transport as a major mode of distributing petroleum products while pipeline transport is limited due to underutilization and vandalization. Movement of products in large quantities sometimes necessitates the use of sea as the mode of transportation. Marine tankers and coastal vessels are used for coastal transportation of petroleum products and to ferry from the coastal refineries of Warri and Port Harcourt, to Lagos.

The most suitable means of transportation of liquid substance is the pipeline. Hence PPMC uses pipelines frequently to convey products from refineries to depots which are located in strategic places across the country. However, according to Kupolokun (2006), over 75% of the pipelines have been vandalized, and are not currently in use. The petroleum products available for distribution through an elaborate 3,949 kilometres of pipelines used to be intercontinental to 21 widely dispersed depots. The products were obtained either from the four local refineries or in the event of a supply short-fall from offshore refineries by way of import of processed Nigerian crude oil. In some cases, and mostly through vandalization, these pipelines burst into flames, causing serious damages to life and property. By multiplier effect, the environmental, economic and social negative impact of such damages is usually enormous. In most cases, the four refineries produce about 61% of the total petroleum needs of the country. The distribution of petroleum products is facing a lot of challenges in the Nigerian environment (Ehinomen and Adeleke, 2012).

### 2.3.7 Haulage of petroleum products in Nigeria and elsewhere

Ehimomen and Adeleke (2012) assessed the distribution of petroleum products in Nigeria. The findings of the study revealed that low capacity utilization of refineries poses a lot of challenge to NNPC on the distribution of petroleum products, which result to petroleum products shortage and eventual importation of the products. This study only examines the capacity utilization and did not consider the cost, time, distance and constraints of petroleum products distribution.

Onwioduokit and Adenuga (2000) determined the factors of urbanization on the distribution of petroleum products in Nigeria's urban centers. Such factors include gross domestic product (GDP), proportion of urban population, contribution of agriculture to GDP, contribution of manufacturing to GDP and contribution of services to GDP. The findings of the study revealed as follows: first, urbanization has a positive impact on the consumption of liquid petroleum gas (cooking gas); second, the elasticity for petrol shows a positive trend; third, the consumption of household kerosene is negatively correlated, showing that demand for kerosene decreases with urbanization. However, three major weaknesses have been observed in this study, which call into question the accuracy of its results. First, the variables used in this study, especially as they concern the premium motor spirit (highway transportation fuel) are wrong parameters and are therefore incapable of estimating the elasticity of demand for the product. Second, the study did not cover the rural areas where 70 percent of the Nigerian populations reside. Third, this study excluded automotive gas oil (diesel) from the analysis in spite of the fact that the product is among the three most important products being consumed in Nigeria.

Alatarighabofa (2010) studied on the impact of production scheduling on the distribution performance of petroleum products by KRPC and discovered that the production scheduling is

not computerized which led to distribution of petroleum products to specific marketers. Also, distribution was based on first come first serve. However, it was recommended that KRPC needs to be computerized to aid effective distribution and production planning.

Eke and Enibe (2007) examined optimal scheduling of petroleum products distribution in Nigeria. The objective was to determine an efficient and equitable distribution of three blends of petroleum products. Post-optimality analysis was performed investigating the effect of varying supply, demand and distribution from refineries to storage depots or selling points. The study reveals that any variation in supply, demand and transportation cost changes the optimal solution.

Furthermore, Zhen (2011) assessed pipeline and vehicle transportation problems in the petroleum industry. Based on this study, petroleum product logistics was divided into transportation of petroleum products by pipeline or railway transport from the refineries to oil depots and tanker (road transport) was used to distribution from oil depots to oil stations. The study revealed that transportation of petroleum products was faced with three problems that can be solved by mixed integer programming model and that oil product transportation costs account for a proportion of sales fees in the Chinese petroleum industry that is considerably higher than the average international level. Hence, reducing costs incurred from the transportation of oil products has become a highly important problem for Chinese oil companies.

Similarly, Samari (2010) studied minimizing transportation cost of petroleum products through distribution networks linking depots operated by bulk oil storage and transportation company limited (BOST) in Ghana using transportation model. The transportation model deals with the distribution of petroleum products from several points of supply (sources) to a number of points of demand (destination) such that the total transportation cost is minimized. The study

revealed that the petroleum product distribution network linking all the five petroleum products storage depots in Ghana showed that the bulk transportation cost of products can be reduced by 14.16 percent.

Hughes (1971) sets up a network model to determine where to locate the terminals with respect to customer distribution sites. The efficient ways of loading and unloading into the storage tanks at oil terminals (Christofides *et. al*., 1980). The transportation costs involved in loading and unloading these storage tanks are not investigated, additionally the study did not address the terminal profits. Simulation-based short term scheduling of crude oil from port to refinery tanks, distillation unit, agent-based crude procurement and effective distribution across Europe (Cheng and Duran, 2004; Chryssolouris *et. al*. 2005).

According to Abduljabbar *et. al*. (2011), decision support system based on simulation and stochastic optimal control in the transportation of petroleum products brings important advantages in process costs and lead-times, while the resulting possibility of smaller and more frequent orders means reduced inventory costs using ARENA software and Visual Basic application/transportation system.

In conclusion, the fact that most of the review work for the study were based on issues such as the distribution of the petroleum products, performance rating of various modes, factors of urbanization on the distribution of petroleum products, optimal scheduling of petroleum products distribution, pipeline and vehicle transportation problems in the distribution of petroleum products. An examination of all these studies reveal that most of them did not consider an indepth comparative analysis of the various modes used in hauling petroleum products from the depots to the final destinations. It is against this background that this study intends to determine the flow pattern of petroleum products, constraints associated with

transporting petroleum products by modes of transport and to compare the transport cost and time. It is this knowledge gap therefore, that this study hopes to link with a view to contribute to knowledge.

# CHAPTER THREE: STUDY AREA AND METHODOLOGY

## 3.1 The Study Area

### 3.1.1 Size of the area

The Kaduna Refinery is meant to serve the northern part of Nigeria which logically has become the present study area. Northern Nigeria has wide stretches of land and great economics potentialities. Its covers about 60 percent of the total area of Nigeria with 19 states and the Federal Capital territory comprising of rural and urban areas. The size of the area makes the market for petroleum products large.

### 3.1.2 Relief

The general relief of the study area is an undulating plain, with areas along the flood plains of the river being lower than those on the upland sections, and occasional rock outcrops in some parts of the area. Northern Nigeria is majorly lowlands which are usually associated with various rocks such as alluvial deposits, limestone, sandstone, shale, clay and so on, the valley of river Niger, the Sokoto plains and the Chad basin. The relief is generally below 300m which makes the terrain not very difficult for laying and maintaining pipelines. The relief is to a large extent controlled by the geology (Iguisi, 1996). However, there is presence of highlands in the north central area which lies within the centre of Northern Nigeria and covers one-fifth of the area.

### 3.1.3 Drainage

Northern Nigeria is drained by the Niger and Benue River which have many tributaries such as River Kaduna, River Gongola and River Sokoto. In the study area, there are rivers which

drain into the inland drainage basin of Lake Chad. Many rivers in northern Nigeria rise from the north central plateau. The Hadejia, Komadugu Gana and Gongola flow to the east, the Sokoto, Kaduna, Mariga and Gurara flow westward to the Niger, while other small rivers like the Mada and Gbako flow south-wards.

### 3.1.4 Climate

The study area has a tropical continental climate (Aw) with distinct wet and dry seasons, reflecting the influence of tropical maritime air mass (mT) and Tropical continental air mass (cT) which alternate over the country. When mT which originates from the Altantic Ocean, prevails over the area, it brings the rainy season while cT originates from the Sahara desert, it brings in the dry season with cold and dusty air that occasionally limits visibility and reduces solar radiation bringing in harmattan condition in the area (Iguisi, 1996). Northern Nigeria experiences four distinct seasons:

(i) Dry & Cold season – from end of November to February

(ii) Dry & Hot season – from March to beginning of May

(iii) Wet & Warm season – from mid May to beginning of October

(iv) Dry & Warm season – from mid October to mid November

Northern Nigeria has mean monthly minimum and maximum temperatures of 15.9$^{o}$C and 35.35$^{o}$C with a range of about 19.45$^{o}$C. The highest temperatures are being recorded in March and April and the lowest are being recorded in December and January. Average annual rainfall in the area is about 1530mm; it ranges from 0.0mm from November to February and 825.0mm in August, which is the wettest month (World 66 Magazine, 2011).

### 3.1.5 Vegetation

Northern Nigeria is located within the Northern Guinea Savannah, Sudan Savannah, Sahel Savannah and Montane Vegetation zone of Nigeria. Climate is the major factor that influences vegetation. The natural vegetation of this zone consists of scattered trees interspersed with tall grasses; it is expected to have a continuous cover of well-developed trees, some 8 -15 metres tall. However, human activities associated with urbanization, intense cultivation, grazing and bush burning have seriously modified the vegetation to the extent that now, trees are most often found only as ornamental ones, comprising mostly of exotic species and it's classified as open and park-like grassland.

### 3.1.6 Population

Northern Nigeria is mainly made up of the Hausas and Fulanis. Most of which are farmers, traditionally depending on crops such as guinea corn, millet, cotton and groundnut. The long dry season (November – May) gives opportunity for them to engage in crafts and local industries. Some areas in northern Nigeria are densely populated with density of over 200 persons per sq km, in areas like Kano, Kaduna, Zaria and Katsina. The estimated population of northern Nigeria is about 80 million (FRN, 2009) which make the area have large market for petroleum products.

### 3.1.7 The economy

Northern Nigeria has roads, railway, pipeline and air transport connecting it to the other parts of the country. It has major rail junctions and passenger points for trains, also house the first airport in Nigeria (Aminu Kano International Airport) and vast road networks across the

locations. It is esteemed for hosting military establishments, federal parastatals, industrial layouts and residential areas. In terms of economic activities in northern Nigeria, Kano, Kaduna, Zaria and Jos is highly significant. Some of the industrial establishment include, textile mills, automobile assembly plant, agro-allied industries, international trade fair centers, important educational institutions, large scale manufacturing centers, cotton processing plants, tobacco processing company, international markets and Kaduna refinery which is centrally located within northern Nigeria. Another major economic activity is agricultural production which northern Nigeria is well-known for such as animal rearing, livestock resources, cash crops production like cotton, ginger, groundnut and soya beans. Crops such as guinea corn, millet, cowpeas, cassava, cocoyam, yam and pepper are also produced in northern Nigeria which boosts economic activities and the economy. In northern Nigeria, it is more economical and easy to develop transport infrastructure due to the nature of relief and availability of land space. Figure 3.1 shows the transport infrastructure of Nigeria.

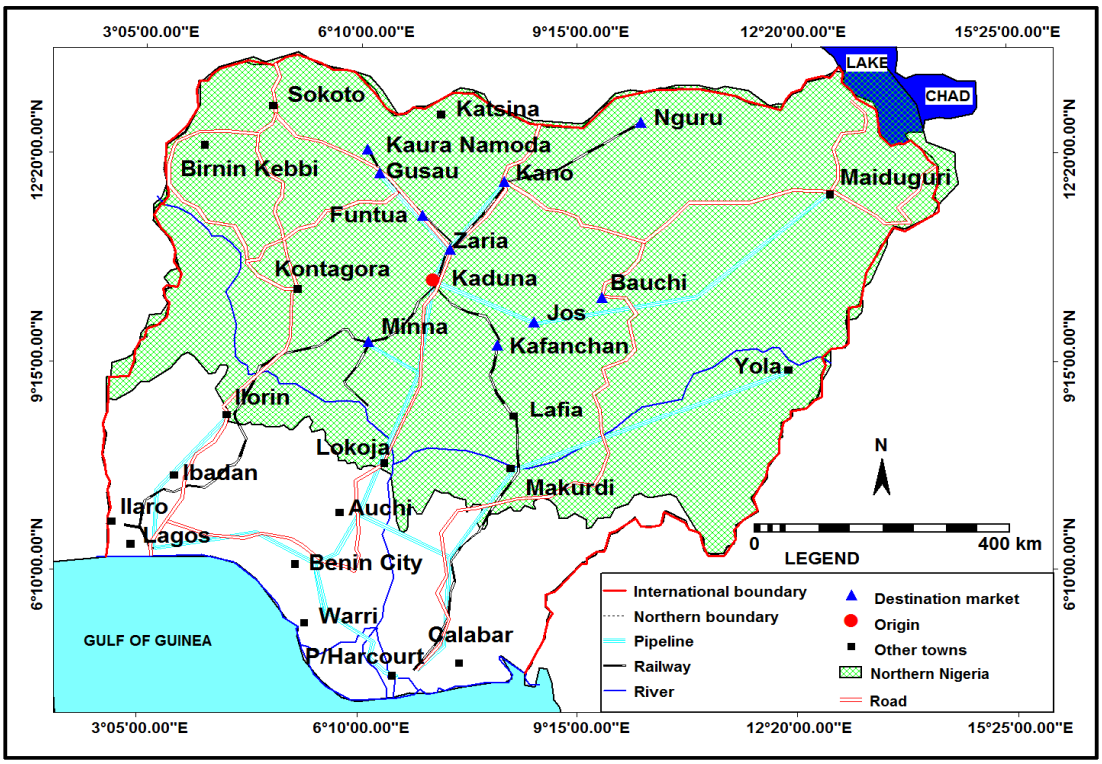



**FIGURE 3.1: TRANSPORT INFRASTRUCTURE IN NIGERIA**

Source: Adapted and Modified from Julius Berger Road Map of Nigeria, 2000

## 3.2 Methodology

This section examines the types of data required, sources of data, sample size, sampling techniques and analytical techniques adopted for this study.

### 3.2.1 Types of data required

In order to achieve the aim and objectives of this study, data on the location of petroleum products distribution, variation of quantity of petroleum products supplied to various locations, the cost, time and constraints of transporting the petroleum product by road, rail and pipeline were collected from respondents (tanker drivers), PPMC and the Nigerian Railway Corporation. The data has aided the validity and reliability of the research.

### 3.2.2 Sources of data

The basic sources of data adopted in this study are the use of primary and secondary data source.

#### 3.2.2.1 Primary Source

Questionnaire survey and interviews were used to elicit the information required for the research. The questionnaire contained close-ended questions aimed at eliciting responses that can aid the understanding of the transport cost of haulage system of petroleum products by road, rail and pipeline transport in the study area. The questionnaire contained both open and closed ended questions which elicit information on such as the cost of transport by road, rail and pipeline, timeliness of delivery of petroleum products by road, rail and pipeline, constraints associated with petroleum products haulage from the refinery to various destination by road, rail and pipeline. Interviews were also conducted to collect data on the cost, time and distance of petroleum product haulage by pipeline and rail from Pipeline and Products Marketing Company and Nigerian Railway Corporation respectively.

### 3.2.2.2 Secondary Source

The secondary sources of data was Kaduna Refinery and Petro-chemical Company library, Pipelines and Products Marketing Company (PPMC) archives and Nigerian Railway Corporation, where the information on cost of transporting petroleum products by rail and pipeline, constraints on the distribution of petroleum products, the time involved in transporting petroleum products by rail and pipeline were obtained. The data from these secondary sources were useful in carrying out comparative analysis of moving petroleum products by rail, road and pipeline transport.

### 3.2.3 Sample Size and Sampling Techniques

The sample population for questionnaire administration was based on the stakeholders in the transportation of petroleum products (tanker drivers). The number of registered tankers that convey petroleum products from KRPC is 1,712. On the average about 158 tankers are supplied with petroleum products per day when refinery is at full production capacity.

Yamane (1967:886) formula to calculate sample size was adopted for this study, at significance level of 95% while the precision level was 0.07. The sample size resulted to a total of one hundred and eighty-two (182) respondents.

$$n = \frac{N}{1 + N(e)^2}$$

Where, n= sample size, N =Population size and e = level of precision (0.07)

Systematic sampling technique was employed to select respondents because the same tanker driver was not supplied every day. The administration was done for 10 working days, at an average of 18 respondents per day.

The questions were constructed to find out the factors influencing the cost of transporting petroleum products by road, rail and pipeline, the degree of challenges faced and the pattern of distribution. Each of transport modes under consideration here are assessed on the criteria of rates charged delivery time, availability, reliability and safety, volume of petroleum, its value and length of haul.

### 3.2.4 Analytical Techniques

The methodological approach used by Gordon (1997) in comparing the transportation cost analysis in East Africa, was adopted in this study objectives. The study team in East Africa collected data and information through the use of questionnaire and interview on transportation cost to and from the two main sea ports of Mombasa and Dar-es-Salam to selected destinations by rail, road and lake. The difference in distance of routes from various origins to the destinations, the transit time and cost was obtained and analyzed for rail, road and lake, to identify the impact of transportation cost on goods movement and its constrain on East Africa domestic and international economy.

Proportional flow map was used to summarize the data on the pattern of flow by which petroleum products are delivered. The constraints that were revealed by the responses of the truck drivers were subjected Kruskal Walli analysis of variance (K-W). The K-W test is an extension of Mann-Whitney U test. According to Morgan *et al*., (2004:158) Kruskal-Wallis test and ANOVA have similar power to detect a difference. This methodological approach was also adopted by Ubogu (2010) to analyze the problems associated with unimodal transportation of Port-hinterland freight in Nigeria.

Comparative analysis was used to determine the variation in costs and time involved in transporting petroleum products by rail, road and pipeline. This was done by examining the difference between the cost of transporting petroleum products per litre kilometer by rail, road and pipeline to the identified locations and the time difference. Student t-test was also used to evaluate the cost and time difference in the transportation of petroleum products by rail, road and pipeline. Descriptive statistics were also employed.

# CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

## 4.1 Introduction

This chapter analyses the data and then presents the results obtained from the field survey. The data was analyzed using the Statistical Package for Social Sciences (SPSS) and Ms Excel. The result is presented using frequency distribution and the discussion is based on the result of the findings. This section reveals the analysis of socio-demographic characteristics of the respondents, the constraints, the distance, cost and time of transporting petroleum products by road, rail and pipeline.

## 4.2 Socio-demographic characteristics of the Respondents

The information presented here is about the 182 tanker drivers sampled for this study. The emphasis on tanker drivers arises as a result of their being the source of information on the movement of petroleum products from Kaduna refinery to the selected destinations.

### 4.2.1 Age distribution

The age of tanker driver has significant implication on the performance and behaviour of tanker driver on the road. The age categorization was based on the fact that the minimum driving age in Nigeria is 18 years. In other words, the categorization is a reflection of economically productive segment of the population. Age distribution as shown in Table 4.1 reveals that, the age group of 33 – 37 years has the highest proportion of respondent which represents 26.9 percent, followed by 23.6 percent for the age of 38 – 42 years while 18 – 22 years accounts for the least representing 0.5 percent. In general, the result indicates that the predominant age group

of the petroleum tanker drivers surveyed falls between the ages of 28 – 52 years which lies among the independent age. Overall, this age range accounts for 96.6 percent.

**Table 4.1 Age distribution of the respondents**

| Age group (Years) | Number of respondents | Percent |
|---|---|---|
| 18 – 22 | 1 | 0.5 |
| 23 – 27 | 5 | 2.7 |
| 28 -32 | 14 | 7.7 |
| 33 – 37 | 49 | 26.9 |
| 38 – 42 | 43 | 23.6 |
| 43 – 47 | 28 | 15.4 |
| 48 – 52 | 33 | 18.1 |
| 53 and above | 9 | 4.9 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012.**

Table 4.1 shows that the age of the tanker drivers has many significant implications for the performance potentials of the transport industry and most active group in the transport industry. The biological age and length of service has close relationship with professional competence, efficiency and risk indicators of petroleum product tanker driving (Bashkireva and Khavinson, 2001). The age structure of the sample tanker drivers shows a characteristic "*n*" distribution pattern. This result is similar to findings of Ubogu *et. al* (2011). From this result, it is apparent that the extremely active age group is involved in tanker driving. According to Fergusen (2003), teenage drivers are inexperienced with immature judgment and have the desire to take risks. One of the reasons made known by the tanker drivers for the age group was the years it takes to learn tanker driving and the tedious nature, which also has gendered implications.

### 4.2.2 Marital Status

Marriage has great impact on the attitude and skills of tanker drivers by making them more responsive to rules and regulation on the road, it also influences their exposure to risk taking. That is, married tanker drivers exposes themselves to less risk on the road due to the responsibilities they are engaged in than single tanker drivers.

**Table 4.2 Marital Status of the respondents**

| Marital Status | Number of respondents | Percent |
|---|---|---|
| Married | 144 | 79.1 |
| Single | 12 | 6.6 |
| Divorced | 17 | 9.3 |
| No response | 9 | 4.9 |
| Total | 182 | 100.0 |

**Source: Field Survey, 2012**

In Table 4.2, most of the petroleum tanker drivers are married representing 79.1 percent of the respondents, 6.6 percent are single while 9.3 percent are divorced. However from the result, it can be seen that most of the tanker drivers are married because of the nature of their job that demands maturity.

### 4.2.3 Educational Status

The educational level of the tanker driver has implications for the use of road as it helps drivers to understand the various road signs, traffic rules and regulations necessary for effective operations while driving on the roads. Table 4.3 shows the educational status of the respondents.

**Table 4.3 Educational Status of the respondents**

| Educational Status | Number of respondents | Percent |
|---|---|---|
| Non formal education | 37 | 20.3 |
| Primary education | 63 | 34.6 |
| Secondary education | 70 | 38.5 |
| Tertiary education | 7 | 3.8 |
| No response | 5 | 2.7 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012.**

The educational status as shown in Table 4.3 reveals that 38.5 percent has secondary education, 34.6 percent has primary education while 3.8 percent has tertiary education. From the result, it can be seen that the petroleum tanker drivers has either formal or informal education but the level of their education greatly influence their attitude and skills behind the steering when driving.

## 4.3 Employers of tanker drivers

Various registered organization transport petroleum products from the refinery to their destination for final consumption by consumers. Table 4.4 reveals that most of the petroleum tankers drivers work with other registered marketer representing 52.8 percent, followed by those that work for NNPC representing 15.4 percent, while 0.5 percent each work for TOTAL, SHIRAH, LINAB, LIKORO and CHEVRON organization respectively. In general, the result indicates that most petroleum tanker drivers work for independent marketers. The major role of independent marketers is to contract for petroleum products supply from refineries in line with prescribed regulations, supply and market petroleum products throughout the country, ensure that onward delivery of petroleum products from regional depots to retail stations, distribute petroleum products to designated petrol filling stations at the regulated price and ensure that road tanker drivers comply with stipulated regulation while other marketers distribute petroleum product to their privately owned petrol filling stations and inflate their prices, also they choose their targeted consumers, for example, other marketers can choose to horde and sell to “black marketers” who later sells at exorbitant prices.

**Table 4.4 Name of organization that tanker drivers work with**

| Name of Organization | Number of respondents | Percent |
|---|---|---|
| Other registered marketers | 96 | 52.8 |
| AGIP | 6 | 3.3 |
| AP | 15 | 8.2 |
| TOTAL | 1 | 0.5 |
| CHEVRON | 1 | 0.5 |
| CONOIL | 8 | 4.4 |
| LIKORO | 1 | 0.5 |
| LINAB | 1 | 0.5 |
| MOBIL | 5 | 2.7 |
| MRS | 11 | 6.0 |
| NNPC | 28 | 15.4 |
| OANDO | 6 | 3.3 |
| SHIRAH | 1 | 0.5 |
| TEXAC0 | 2 | 1.1 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012.**

## 4.4 Movement of petroleum products by road

The movement of petroleum product is majorly done by tankers on the road in Northern Nigeria. In this section, the patterns of distribution, number of day(s) taken to get to their destination, frequency of trips, and quantity of petroleum product transported were analyzed. The major determinant of the pattern of distribution is spatial location, the population, the economic activities, the level of demand, distance from the petroleum depots and the rate of energy consumption. Distance is not a determinant of the volume of distribution. Table 4.5 shows clearly that the locations (Zaria, Kano, Gusau and Bauchi) with high volume of distribution was not determined by the distance from the refinery but the economic, political, commercial, social, education and geographical location were the main determinant of the volume of distribution and the high rate consumption of energy in those location. Apart from Zaria which has nodal function with the highest concentration of Federal agencies in Northern Nigeria, for example, NCAT, A.B.U, Polytechnic, F.C.E, NITT, Army Schools and

establishment as well as research institutions. Others are state capitals (Kano, Gusau and Bauchi) where major activities of the state take place and have high concentration of population and it is obvious that these locations are major urban centers.

**Table 4.5 Distribution of the movement of petroleum products by road**

| Location | Distance from KRPC | Number of tanker drivers | Quantity of products moved within 10 days in liters | Percent |
|---|---|---|---|---|
| Zaria | 100 km | 24 | 792,000 | 13.2 |
| Funtua | 143 km | 12 | 396,000 | 6.6 |
| Kafanchan | 171 km | 16 | 528,000 | 8.8 |
| Kano | 292 km | 34 | 1,122,000 | 18.7 |
| Gusau | 231 km | 22 | 726,000 | 12.1 |
| Kaura namoda | 279 km | 11 | 363,000 | 6.0 |
| Bauchi | 442 km | 22 | 726,000 | 12.1 |
| Nguru | 450 km | 11 | 363,000 | 6.0 |
| Jos | 310 km | 13 | 429,000 | 7.1 |
| Minna | 327 km | 17 | 561,000 | 9.3 |
| **Total** | | **182** | **6,006,000** | **100.0** |

**Source: Field Survey, 2012**

The table indicates that the distance of the locations considered, do not have any determination on the volume of petroleum product distribution.

Similarly, Figure 4.1 clearly display the proportional flow of petroleum products, Kano has the highest in-flow of 1,122,000 liters of petroleum products within ten days covering 18.7 percent, followed by Zaria 13.2 percent, Nguru and Kaura- namoda experience the lowest in-flow of 6.0 percent respectively. Some major reasons may be responsible for Kano recording the

highest proportion. Kano is comparatively nearer to the refinery. Secondly, the economic activity is another factor. Kano is well-known for its high commercial function and high population which consume much fuel (energy) for her daily activities. The location being the State capital also makes other local government depend on it. Zaria, which is the next to Kano in the consumption and demand for petroleum products, can be seen as an educational centre with high population of people and vehicular usage.

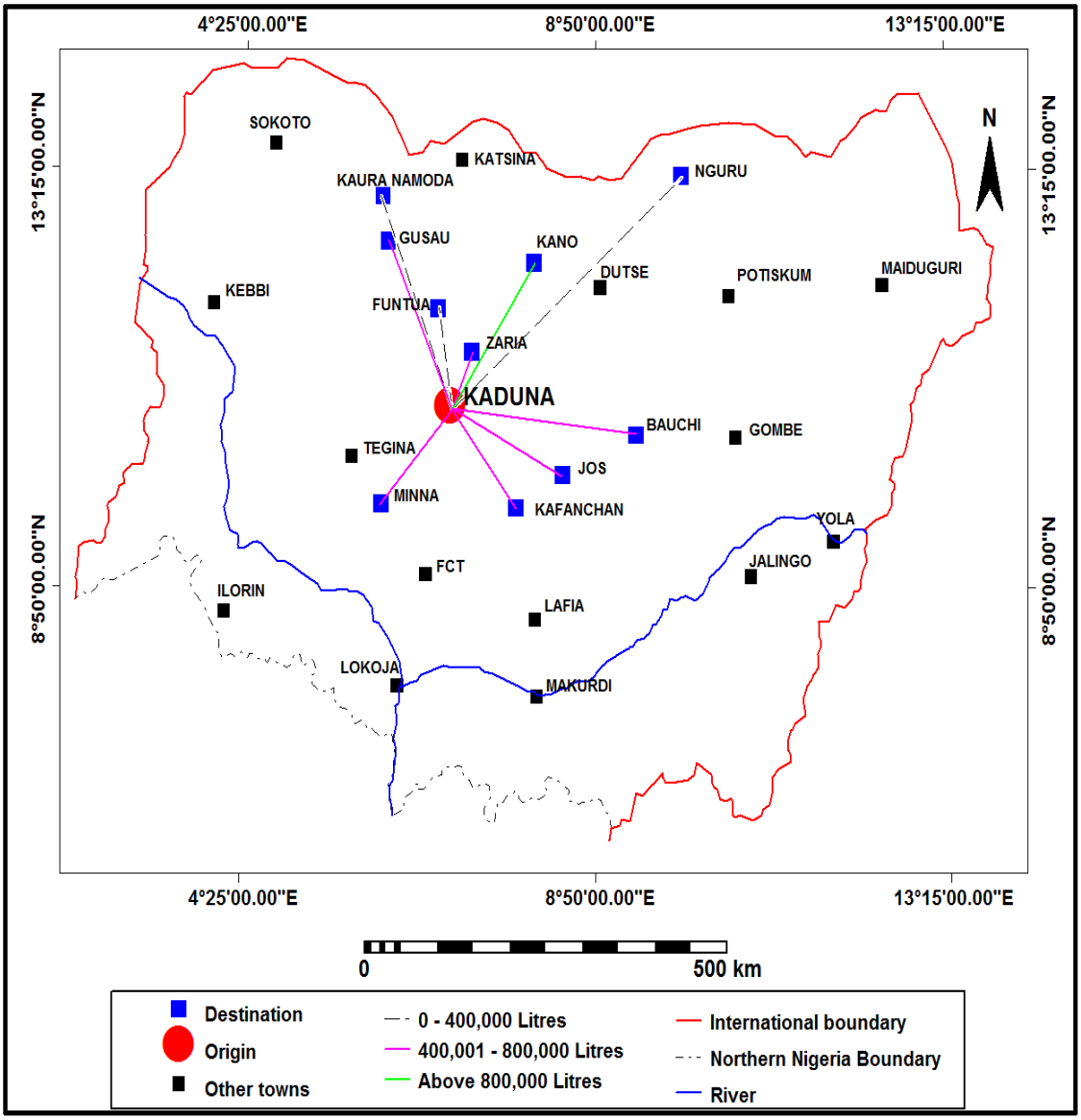



**FIGURE 4.1: PROPORTIONAL FLOW OF THE DISTRIBUTION OF PETROLEUM PRODUCTS BY ROAD TRANSPORT**

The result indicates that Nguru and Kaura-namodas' supply is low because population and economic activities in these locations are very few. From Figure 4.1, it is obvious that most locations that are state capital or economic centres such as Bauchi, Jos, Minna and Kafanchan consumes much petroleum products, which makes the demand and distribution relatively high to such areas.

## 4.5 Number of days taken to arrive at the destination

Just-in-time improve profits, return on investment by reducing inventory levels, reducing variability, improving product quality, reducing delivery lead times and reducing other costs. The Just-in-time system aims to coordinate the flow of products so that supply exactly matches demand, and products arrive for use just as they are needed; the right product in the right place at the right time. The reason for just-in-time is to avert some operational problems such as short deliveries and fuel evaporation because the longer the petroleum products spend on the road the higher the rate of evaporation and propensity of the tanker drivers to dispose some products which leads to short deliveries. Table 4.7 shows the number of days taken to arrive at the destination.

**Table 4.6 Number of days taken to arrive at the destination**

| Day (s) | Number of tanker drivers | Percent |
|---|---|---|
| 1 day | 148 | 81.3 |
| 2 days | 30 | 16.5 |
| 3 days | 3 | 1.6 |
| No response | 1 | 0.5 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012**

Table 4.6 reveals that 81.3 percent takes one day to get to their destination, 16.5 percent takes two days to get to their destination while 1.6 percent takes 3 days to get to their destination. This result indicates that most of the petroleum tanker drivers get to their destination within 24 hours, however, from the field survey and discussion with the drivers, it was deduced that this 24 hours trip is realistic when they do not encounter any mechanical problem or challenge on the road. The number of day(s) covered is relative to the distance of the destination.

## 4.6 Frequency of Trips

An optimal trip frequency schedule can be studied as transportation planning and management task in real practice. The scheduling problem leads to the time distribution of shared resources (petroleum product). The number of required trips is determined by the capacity of the tank and the time period. Table 4.7 shows the frequency of trips.

**Table 4.7 Frequency of Trips**

| Response | Number of respondents | Percent |
|---|---|---|
| Every week | 148 | 81.3 |
| Once/twice a month | 33 | 18.1 |
| No response | 1 | 0.5 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012**

Table 4.7 indicates that 81.3 percent tanker drivers travel to their destinations every week while 18.1 percent travel to their destination once or twice a month. This reveals that the movement of petroleum products to the most identified locations occurs on weekly basis. This indicates that the distance and time covered is relatively short, that is, petroleum product tanker drivers can travel from origin to destination every week for supply.

## 4.7 Constraints associated with petroleum products movement by road

The methodological technique adopted here is to present the list of a set of operational problems to the tanker drivers, who were asked to rank-order them according to the problems they encounter while transporting the petroleum products in the order of 1 to 7. The most challenging is ranked 1 while the least challenging is ranked 7. These problems include bad roads, theft/robbery, accident, traffic congestion, mechanical problem, delay at police and military check points, short delivery due to evaporation, inter-state revenue task personnel, delay in salary and off-loading.

### 4.7.1 Rank-order of operational problems encountered by the tanker drivers

The rank – order of the problems is displayed in Table 4.8 using Kruskal-Wallis non - parametric test for repeated measure analysis. Out of the 10 constraints listed for the respondents to rank, only four operational problems as shown in Table 4.8 was ranked 1. As shown in the table, the trucking constraints rank-order 1 reveals that delay at police and military check point emerged the most problematic constraint with a mean of 1.72 and a standard deviation of 0.843. This was followed by mechanical problem developed by the tanker on the road with a mean of 2.17 and a standard deviation of 1.082. Bad roads followed mechanical problem with a mean of 2.58 and standard deviation of 1.297, traffic congestion was also ranked 1 with a mean of 3.79 and standard deviation 1.502. Of all the respondents who ranked the listed problems as the extremely challenging, 45.1 percent of the respondents ranked delay at police and military check points as the first, which was followed by mechanical problem (36.3 percent), bad roads (14.8 percent) and traffic congestion (3.8 percent).

**Table 4.8 Rank-order of operational problems encountered by the tanker drivers**

| Rank | Operational problems | N | Mean | Standard deviation | Variance | Number of respondents | Percent |
|---|---|---|---|---|---|---|---|
| 1 | Delay at Police and military check points | 182 | 1.72 | 0.843 | 0.711 | 82 | 45.1 |
| 2 | Mechanical problem | 182 | 2.17 | 1.082 | 1.170 | 66 | 36.3 |
| 3 | Bad roads | 182 | 2.58 | 1.297 | 1.681 | 27 | 14.8 |
| 4 | Traffic congestion | 182 | 3.79 | 1.502 | 2.255 | 7 | 3.8 |
| **Total** | | | | | | **182** | **100** |

**Source: Field Survey, 2012**

Delay at police and military check points, mechanical problem and bad roads were ranked first 3 problems because of the state of insecurity in Northern Nigeria that have led to road check point at several points, the nature of trucks, mechanical parts of the trucks and tyres purchased for replacement are usually fairly used which leads to impromptu breakdown of trucks. Due to the expensive nature of trucks and tyres, truck owners settle for fairly used trucks and their parts which have effect on the road. Poor maintenance and exerted pressure because of increase in vehicular population on the road worn out the capability of the road and it is left in a depilating state which affect the effective distribution process. The recurrent complaints of delays have sometimes been ascribed to the poor nature of roads in the country. The trucking industry in Nigeria has had to contend with poor maintenance of the roads which leads not only to high rates of accidents and cost of vehicle maintenance but also reducing the travel speed of trucks (Kanawa, 2007).

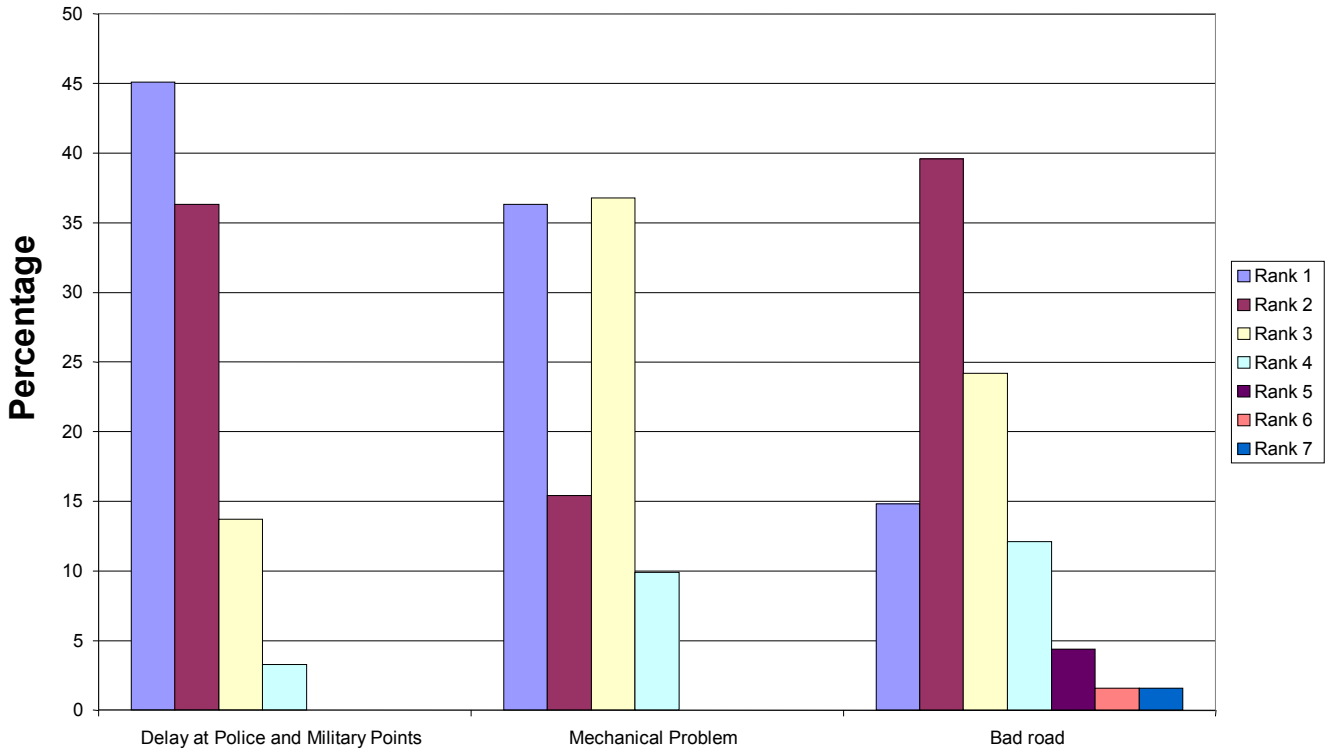



**Figure 4.2 Percentage distributions by delay at police and military points, mechanical problem and bad road.**

Further evaluation of the three problems that were ranked most in order of most challenging showed that more respondents ranked them first in importance than in other categories. For example, 45.1 percent of the respondents listed delay at police and military check points as the first major problem. Again, 36.3 percent ranked it second, 13.7 percent ranked it third, 3.3 percent ranked it fourth, fifth, sixth and seventh position did not rank it at all (see figure 4.2). Indeed, delay at police and military check points is the only problem where 45.1 percent of those who identified it ranked it as the most challenging. This observed degree is not surprising as Northern Nigeria is facing consistent predicament in the past few years. This result is similar to the findings of Ubogu *et al* (2011) that 42.1 percent identified bad roads as the major

cause of increased turn-around of trucks and 40.1 percent of the respondents listed harassment from law enforcement agencies as the first major problem.

Mechanical problem was listed the second most important problem by the respondents. Out of the 182 tanker drivers interviewed, 36.3 percent ranked it first, 15.4 percent ranked it second, 36.8 percent ranked it third and 9.9 percent ranked it fourth. Figure 4.2 also shows the percentage distribution by rank-order of bad road as problem of transporting petroleum product by road. Bad road was listed the third most challenging problem with 14.8 percent ranking it first, 39.6 percent ranked it second with the remaining third to seventh accounting for 24.2 percent , 12.1 percent, 4.4 percent, 1.6 percent and 1.6 percent respectively. This signifies that the state of roads in Northern Nigeria can affect smooth distribution of the product and turn-around time.

### 4.7.2 Correlation matrix of the trucking problems

This study further examined the extent of the association between the problems under investigation. Table 4.9 shows the spearman's correlation matrix for the ten problems tagged $X_1$ (Bad roads), $X_2$ (Theft/Robbery), $X_3$ (Accident), $X_4$ (Traffic congestion), $X_5$ (Mechanical problem), $X_6$ (Delay at police and military check points), $X_7$ (Short delivery), $X_8$ (Inter-state revenue personnel), $X_9$ (Delay in salary) and $X_{10}$ (Delay in off-loading). It is obvious from the correlation matrix that 5 pairs of the variable were related. Table 4.9 shows the correlation matrix of association of the problems of moving petroleum products by road transportation.

**Table 4.9 Correlation matrix of association of the problems of moving petroleum product by road transportation**

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1.000 | -0.207 | -0.154 | -0.209 | -0.408 | 0.087 | -0.192 | 0.080 | 0.297 | 0.81 |
| $X_2$ | | 1.000 | 0.238 | 0.144 | -0.016 | 0.334 | -0.204 | -0.064 | -0.334 | -0.478 |
| $X_3$ | | | 1.000 | -0.008 | 0.160 | 0.005 | 0.059 | -0.104 | -0.137 | -0.375 |
| $X_4$ | | | | 1.000 | -0.15 | -0.66 | 0.132 | -0.084 | -0.336 | -0.025 |
| $X_5$ | | | | | 1.000 | -0.449 | 0.314 | 0.055 | -0.119 | -0.064 |
| $X_6$ | | | | | | 1.000 | 0.46 | -0.176 | -0.147 | 0.019 |
| $X_7$ | | | | | | | 1.000 | -0.482 | -0.177 | 0.027 |
| $X_8$ | | | | | | | | 1.000 | 0.006 | -0.56 |
| $X_9$ | | | | | | | | | 1.000 | -0.103 |
| $X_{10}$ | | | | | | | | | | 1.000 |

**Source: Field Survey, 2012**

From the Table 4.9, pair $X_{10}$ by $X_1$ reveals that the higher the bad roads the higher the delay in off-loading because bad roads will affect the tankers' speed, thereby increasing the number of days taken for delivery of petroleum products and off-loading. Similarly, $X_7$ by $X_6$ indicates that the higher the delay at police and military check points, the higher the short-delivery because petroleum products evaporates and the higher the delay, the higher the rate of evaporation and manipulation by truck drivers that eventually leads to short-delivery. Furthermore, $X_2$ by $X_6$ shows that delay at police and military check points exposes the truck drivers to theft/robbery attack because the longer the tanker drivers are delayed, the longer time spent to their destination which can endanger them to theft/robbery at night. Pair $X_7$ by $X_5$ indicates that the higher the mechanical problem, the higher the short delivery because the tanker drivers will have to spend more days that was unplanned for and incur more expenses that can make them drain petroleum products from the tank to resale to black-marketers in order to get money to solve their mechanical problem and welfare leading to short delivery at the final

destination (Petrol filling station). The correlation matrix provides a useful relationship between the problems.

### 4.8 Constraints of Pipeline and Rail transport

The researcher also got information through oral interview from the personnel who were in charge of information dissemination from Pipeline and Product Marketing Company (PPMC) and Nigerian Railway Corporation (NRC), Kaduna, on the challenges they face in transportation of petroleum product. For pipeline transport, the major challenges it face are insufficient pipeline network, vandalization, insufficient depots, insufficient pump stations and electricity problems. Vandalization is the most challenging constraint to the Pipeline and Product Marketing Company (PPMC). It has created great menace to the environment, life and property and effective distribution of petroleum products by pipeline. Followed by insufficient pipeline network, Nigeria as a whole has 3,949km network of pipelines in five systems (Mbendi, 2011) which are insufficient to distribute petroleum products to the limited depots available. The least challenging constraints to PPMC is the electricity problem because a substitute is provided to generate constant power, however, sometimes the generator set fails and they are left out of production.

The Rail transport experience insufficient liquid tanks, insufficient rail network, poor infrastructural development and neglects from government as the challenges it face. Neglect from government is the most challenging constraint NRC face in the effective distribution of petroleum products. NRC has been sabotage for road tanker owners which have left the NRC in a depilating state in the distribution of petroleum products. The constraint that followed government neglect closely is insufficient liquid tanks. Limited numbers with 35,000 liters

capacity of petroleum products tankers are available at NRC which is a problem in the effective distribution of the product. The least challenging is the insufficient rail network, though Nigeria has a number of rail tracks but more is needed for effective distribution of the products, high maintenance is ongoing as at the time of this research. The steady decline in the availability of locomotives and rolling stock, due to spare parts shortage and maintenance problems, contributes in no small measure to the precipitous drop in the quantity and quality of NRC services. In the early 1990s, for example, only an average of 350 coaches, 4,000 wagons and 40 locomotives were in serviceable condition, out of a stock of 674 coaches, 6,000 wagons and 189 locomotives (CBN, 1992). This is in spite of the fact that, as far back as the early 1980s, the daily requirements were about 150 locomotives, 720 coaches and 7,500 wagons (Babatunde, 1998; Metra Consulting, 1986). When things got worse in the late 1990s, the effort then was to meet the daily requirement of 80 locomotives (Ilukwe, 1998).

### 4.9 Safety of transporting petroleum products by road

A good measure of safety in a transport system is the degree of that transport mode's involvement in accident. Annually, road accidents claim several thousands of lives and properties all over the world. It is also known that Nigeria ranks amongst the leading countries with the highest rate of road accident in the world (Filani and Gbadamosi, 2007, Dos, 2008). A reliable transport system is as good as the safety it provides to products that it handles. Safety is one of the criteria for the selection of the best mode of transportation of petroleum products.

**Table 4.10 Respondents' view on how safe is the transportation of petroleum products by road transport**

| Response | Number of respondents | Percent |
|---|---|---|
| Very safe | 32 | 17.6 |
| Safe | 94 | 51.6 |
| Not safe | 48 | 26.4 |
| I can't say | 8 | 4.4 |
| **Total** | **182** | **100.0** |

**Source: Field Survey, 2012**

Table 4.10 shows that 51.6 percent admits that transporting petroleum products by road is safe and 26.4 percent declare it not safe. This result was based on the opinion of the tanker drivers. The safety of a mode of transport determines how efficient the mode is. The transportation of petroleum product by road is usually not safe because of the high quantity they carry the risk and the nature of Northern Nigeria roads.

## 4.10 Comparative analysis of rail, road and pipeline in petroleum product movement

Determining the variation in costs and time is important in the discovery of the best mode suitable in the distribution of petroleum product from the refinery. The following section therefore considers the variation in distance, costs and time involved in transporting petroleum product from origin to destination (selected locations) by road, rail and pipeline transport as at the time of the survey. Due to the comparative nature of this section, it was discovered that only six locations are connected by the three modes of transport - road, rail and pipeline network which was used for this analysis. This in essence will afford the researcher the basis for comparing them.

Table 4.11 shows the distance of six locations by rail, road and pipeline transport. The impact of distance on cost is such that total transport cost per kilometer generally falls as journey distance increases. As a result, increase in journey distance will result in less than proportional

increases in the total transport cost per vehicle load. Brown and Allen (1998) have argued that as trip length increases, larger and faster roads will generally be used by the truck driver and therefore, the average speed will increase. Another reason for the variation in costs per litre/km is economics of scale which reduces transport costs on heavily used routes (Bradford and Kent, 1979). From Table 4.11, it can be deduced that pipeline transport distances is shorter than the other two modes while rail transport for three locations such as Kano, Kaura-Namoda and Gusau covers relatively longer distances. Despite the distances, the cost of transporting petroleum product by rail and road comparatively, it is obvious that the movement of petroleum product by rail should be quite cheaper examining the cost difference in Table 4.12. Also, the distance of pipeline transport from KRPC to Gusau is 260 km while that of rail and road is 273 km and 231 km respectively, yet the cost and time of transportation is cheaper and faster despite the distance. Distance is one of the major determinants of the transport cost, the farther the location (distance) the higher the cost of transportation.

**Table 4.11 Distance by road, rail and pipeline transport**

| From KRPC to | Distance by road (km) | Distance by rail (km) | Distance by pipeline (km) |
|---|---|---|---|
| Zaria | 100 | 99 | 83 |
| Funtua | 143 | 167 | 126 |
| Jos | 310 | 264 | 166 |
| Kano | 292 | 339 | 223 |
| Kaura-Namoda | 279 | 320 | 262 |
| Gusau | 231 | 273 | 260 |

**Source: Field Survey, 2012, NRC and FRSC Kaduna**

Similarly, Table 4.12 shows the cost involvement by road, rail and pipeline to move 33,000 liters of petroleum products from Kaduna refinery to six locations in Northern Nigeria. A careful look at Table 4.12 reveals that on the average, as much as ₦ 100,000 is needed to transport petroleum product by road to Jos, ₦ 54,885.60 by rail and ₦ 28,073.92 by pipeline. Also the cost of transporting petroleum product from origin to Zaria by road was ₦ 30,000; rail cost ₦ 20,582.10 while pipeline cost ₦ 14,036.96. This reveals that there is a difference in the cost of transporting by these modes of transport while road is more expensive compared to rail.

**Table 4.12 Cost of transporting petroleum products of 33,000 litres by road, rail and pipeline transport in Naira**

| From KRPC to | Distance from refinery | Cost by Road | Cost by Rail | Cost by Pipeline |
|---|---|---|---|---|
| Zaria | 100 | 30,000 | 20,582.10 | 14,036.96 |
| Funtua | 143 | 45,000 | 34,719.30 | 21,309.12 |
| Jos | 310 | 100,000 | 54,885.60 | 28,073.92 |
| Kano | 292 | 90,000 | 70,478.10 | 37,713.96 |
| Kaura-Namoda | 279 | 120,000 | 66,528 | 44,309.44 |
| Gusau | 231 | 100,000 | 56,756.70 | 43,971.20 |

**Source: Field Survey, 2012, NRC and PPMC Kaduna**

Comparing the cost of transporting petroleum products by modes of transportation, it was discovered that pipeline transport is most cost effective mode of transporting petroleum products, followed by rail and thousands of naira could be saved if pipeline transport is adequately employed in movement of petroleum products.

The student-t test values as seen in Table 4.13 indicates that the calculated *t-test* for all the compared means were significant. For instance, the combination of road-pipeline costs shows a t-test value of 4.902, p. <0.004, while rail-pipeline shows a t-test value of 4.744, p.<0.005 and road-rail indicates a t-test value of 3.815, p. <0.012, at 5 degrees of freedom and at

0.05 level of significance respectively. This implies that there is a significant difference in cost of transporting petroleum products by road, rail and pipeline. Therefore, we do not accept the null hypothesis.

**Table 4.13 Student-t test statistics of paired road, rail and pipeline cost on the transportation of petroleum product.**

| | Paired differences | | | | | |
|---|---|---|---|---|---|---|
| | **Mean** | **Std. deviation** | **t-test** | **df** | **Sig. (2-tailed)** | **Interpretation** |
| Road and Pipeline | 49265.007 | 24615.977 | 4.902 | 5 | 0.004 | Statistically significant |
| Rail and Pipeline | 19089.690 | 9856.894 | 4.744 | 5 | 0.005 | Statistically significant |
| Road and Rail | 30175.317 | 19374.558 | 3.815 | 5 | 0.012 | Statistically significant |

**Source: Field Survey, 2012**

Furthermore, the efficiency and cost-effectiveness of a transport system can be attributed to its timeliness. In comparing the time taken to move petroleum product from Kaduna refinery by road, rail and pipeline, it was discovered that pipeline transport takes lesser time to move products. Table 4.14 shows the time taken by these modes of transport in moving petroleum product from origin to destination. Transporting petroleum products from Kaduna to Kaura-namoda takes 570 minutes by road, 305 minutes by rail and 126 minutes by pipeline. This is not surprising as stoppages and other logistical problems such as bad road, mechanical problem and delay at police check points are unbridled with road transport. Subtracting the minutes spent by one mode to another, it was discovered that 179 minutes will be saved, if petroleum products are moved by pipeline as against rail while 444 minutes will be saved when compared to road transport. That is to say, higher quantity can be transported in a short time.

**Table 4.14 Time taken in the transportation of 33,000 liters of petroleum products by road, rail and pipeline transport**

| From KRPC to | Distance from refinery | Time by Road (Minutes) | Time by Rail (Minutes) | Time by Pipeline (Minutes) |
|---|---|---|---|---|
| Zaria | 100 | 150 | 100 | 40 |
| Funtua | 143 | 270 | 158 | 61 |
| Jos | 310 | 510 | 317 | 80 |
| Kano | 292 | 330 | 326 | 107 |
| Kaura-Namoda | 279 | 570 | 305 | 126 |
| Gusau | 231 | 450 | 265 | 125 |

**Source: Field Survey, 2012, NRC and PPMC Kaduna**

In Table 4.14, the time taken by road transport to get to Jos is about 2 to 3 times higher than the time taken by pipeline and rail transport to move the same quantity of petroleum product. From the result, the temporal variation in time could be saved when pipeline is fully maximized in the transportation of petroleum products from the refinery to the nearest depot while road can be used to complement it. Furthermore, pipeline can sustain the movement of petroleum products both at night and by day without hindrance.

Examining student-t test result of the time of transportation in Table 4.15, the result is similar to the result of the cost taken to transport 33,000 liters of petroleum products, in that the compared mean's *t-test* is statistically significant, t value is 3.382, p.<0.020 for road – rail time. The time difference is also significant for rail-pipeline transport with t-value 5.491, p.<0.003 and road-rail transport with t-value 5.358, p<0.003, at 5 degree of freedom and at 0.05 level of

confidence. This also implies that there is a significant variation in the time taken to transport petroleum products.

**Table 4.15 Student-t test statistics of paired road, rail and pipeline time in the transportation of petroleum product.**

| | Paired differences | | | | | |
|---|---|---|---|---|---|---|
| | **Mean** | **Std. deviation** | **T** | **df** | **Sig. (2-tailed)** | **Interpretation** |
| Road and Rail | 134.833 | 97.651 | 3.382 | 5 | 0.020 | Statistically significant |
| Rail and Pipeline | 155.333 | 69.296 | 5.491 | 5 | 0.003 | Statistically significant |
| Road and Pipeline | 290.167 | 132.658 | 5.358 | 5 | 0.003 | Statistically significant |

**Source: Field Survey, 2012**

Generally Speaking, comparing road, rail and pipeline transportation of petroleum products, it can be deduced that pipeline transport in the movement of petroleum product is most-cost effective, considering the distance, cost and time it takes to transport 33,000 litres. From the study, it was discovered that pipeline transport have higher volume capacity to move these products than rail and road transport while rail tankers also have about 2,000 litres capacity higher than road tankers and have higher capacity to move more than one truck at the same time unlike the road tankers. However, the rail transport system is face with the following problems such as: insufficient tankers, lack of good railway network system in distributing the product to all corners of the country, more towns and cities need to be connected with the railway, bad and insufficient locomotives, competition by the road tankers owner and lack of strong law by the government to reduce the usage of road tankers to forestall diversion of the product but

encourage the rail usage. The Pipeline is majorly faced with electricity and sabotage problem otherwise; it works for 24hours per day which is very efficient and cost- effective.

For the pipeline to serve optimally, it needs storage infrastructure in the form of depots and associated array of equipment such as pumps, valves, loading arms and meters as well as generators. Besides, these must be maintained at the highest level of repairs to ensure hitch-free distribution, while a truck will take about three days from Lagos to Kano, the pipeline can carry higher volumes through the same distance within five hours. Though the rail system can carry higher volumes at 300km/day (Higher Speed Trains), speeds of 100 – 150km/hour or 3000km/day is obtainable by pipelines since they operate for 24 hours per day (Ntiense, 2006).

Pipeline transport has been particularly attractive for the uninterrupted movement of liquid and gas, because of its relative cheapness. This cheap cost of moving crude products, as an advantage, is only shared by pipeline, with super tankers. Thus, the economics of scale are particularly evident in pipeline transport, for cost falls sharply with increasing capacities of pipes. The possibility of moving solids in suspension or in capsules and even unsuspended solids through pneumatic pressure has made pipeline transport more attractive. In spite of this, the traditional role of pipeline as the conveyance of liquid and gas continues to predominate (Ikporukpo, 1995).

The advantages of pipeline transport are high capacity, less effect by weather conditions, cheaper operation fee, and continuous conveyance; the disadvantages are expensive infrastructures, harder supervision, goods specialization, and regular maintenance needs (Tseng *et al*., 2005), as regards railway transportation, goods that have low value but bulky are carried. Fixed costs are high because of the installation and maintenance costs. On the other hand variable costs are low. Because the goods are transported with high volume, the costs per unit are

low, so it is a safe transportation mode. Transportation with railway is fast and transportation time is not long. These are the disadvantages of this mode of transportation (Ozkan and Baslıgil, 2009). Railway transport has advantages like high carrying capacity, lower influence by weather conditions, and lower energy consumption while disadvantages as high cost of essential facilities, difficult and expensive maintenance, lack of elasticity of urgent demands, and time consumption in organizing railway carriages (Tseng *et al*., 2005) while in road transportation, accident rates are high than the other transportation modes (Ozkan and Baslıgil, 2009) but road freight transport has advantages as cheaper investment funds, high accessibility, mobility, availability and offers door to door services.

# CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

## 5.1 Introduction

At the beginning of this research, the aim and objectives were outlined which centered on the comparative analysis of transportation of petroleum products by rail, road and pipeline out of KRPC to selected locations in Northern Nigeria. Petroleum products, like any energy distribution cannot be implemented without adequate transport system. An efficient and effective movement of petroleum products from the producing centre to the consumption point requires an extensive and elaborate transport system. The role of transport in logistics and supply chain of petroleum product are numerous especially the expectation from firms to delivering value added services by ensuring the movement of petroleum products to the right place in the right time and at the right quantity, quality and cost. Also, the increasing nature of supply chains in the global economic introduces an increased spatial gap which results in greater transportation cost in most cases. This is apparently displayed in the petroleum sector, as places of supply are geographically far from the markets causing the transportation expenditures incurred by petroleum product firms to increase at a significant amount. Hence, this calls for a most efficient and effective mode of transport in order to have control over service level and expenditure of the transport mode in view of reducing cost. As viewed by Ballou (2004), it is performance that a user buys from the transport system. This chapter presents the concluding part of the study with summary of findings, recommendation, conclusion and policy implications.

## 5.2 Summary of findings

This study relied on both primary and secondary sources of data. Questionnaire was used to obtain the primary data using systematic sampling techniques. Data obtained was subsequently analyzed using both descriptive and inferential statistics. The findings of this study reveal that pipeline transport is the most cost-effective and less challenged mode of transporting petroleum products. The different modes of transport available in the country include road, rail, pipeline, air and waterway regarded as one of the longest in the world.

The investigation revealed that there is more in-flow of petroleum product into central business district areas where economic, educational, physical and social activities are prominent like Kano, Zaria, Bauchi, Minna and Kafanchan with 18.7 percent, 13.2 percent, 12.1 percent, 9.3 percent and 8.8 percent respectively. Also, the constraints associated with delivery operations as identified by the tanker drivers pointed out that delay at police and military check points is the most challenging constraint confronting the transportation of petroleum product by road, while vandalism was reported by PPMC as the most challenging for pipeline transport and insufficient tankers and government neglect was identified by NRC as the most challenging. Other problems in order of ranking include mechanical problem, bad road, traffic congestion, short delivery, delay in off-loading, accident, inter-state revenue personnel and theft/robbery as the least critical problem in the transportation of petroleum products.

Furthermore, this study did not only identify the problems but also carried out a comparative analysis of the costs (monetary and time) of road, rail and pipeline transportation of petroleum products out of KRPC to six selected locations where the three modes were available. For instance, the combination of road-pipeline costs shows a t-test value of 4.902, p. $<0.004$, while rail-pipeline shows a t-test value of 4.744, p.$<0.005$ and road-rail indicates a t-test value of

3.815, p. <0.012, at 5 degrees of freedom and at 0.05 level of significance respectively, in that the compared mean's *t-test* is statistically significant, t value is 3.382, p.<0.020 for road – rail time. The time difference is also significant for rail-pipeline transport with t-value 5.491, p.<0.003 and road-rail transport with t-value 5.358, p<0.003, at 5 degree of freedom and at 0.05 level of confidence. This findings further show that the potentials of the effective use of pipeline transport as a major means of transporting petroleum products from origin to destination (or nearest destination, complemented by other mode) would be cheaper and timely than the use of the road haulage only.

## 5.3 Conclusion

This study has identified the most cost-effective mode of transporting petroleum products. The result indicates that the cost and time involved in transporting petroleum product by pipeline is much cheaper and shorter than rail and road transport, also in terms of safety and maintenance. The major findings of this study shows that the road mode raises more challenges in moving petroleum products such as bad roads, theft/robbery, accident, traffic congestion, mechanical problem, delay at police and customs check points, short delivery due to evaporation, diversion of product, inter-state revenue task personnel, delay in salary, delay in off-loading and old stock of tankers in use. Risk caused by the tank trucks on the roads mostly depends on the general transport intensity of the road section, accident rate of road section and number of tank trucks. Routes by tanks trucks in Nigeria are not regulated, therefore, risk of some routes due to tank truck accidents is larger than the pipeline. Control of tank trucks' routes enables to significantly reduce the total risk of petrol transportation. Optimizing tank trucks; routes according their length and risk indexes, risk will reduce compared to the existing situation. For

further reduction of tank trucks risk, they have to be provided with portable monitoring system such as installation of GPS in the trucks, which in the case of accident or danger due to impermissible changes of controlled parameters, would send an adequate signal according to which an optimal solution would be achieved.

Rail transport is faced with the challenge of limited tankers, network connectivity and sabotage by tanker owners while the major challenge of the pipeline transport is vandalization and insufficient pipeline network. The challenges faced by the movement of petroleum product if adequately check-mate will greatly improve the movement, supply and delivery of petroleum product across the country in terms of transit time, safety, reliability, capability and at a minimized transport cost.

In conclusion, the principal advantages of pipeline transportation are; loss in transit is less in pipeline transportation as compared to other modes; pipeline offers large-scale economies of scale in transportation of liquid petroleum products; environmental impact during construction, operation and maintenance is negligible and reversible which is environment friendly; it can be used to transport multiple products; pipeline transportation is flexible, as the volume transported can be increased/decreased quickly and at negligible cost and operation/maintenance costs are relatively lower. Therefore, as far as the pipeline transportation is concerned, once the pipeline is depreciated, the cost of transportation is only its operation cost, that is, virtually negligible and substantially lower than the corresponding costs for transportation through alternate modes. As such, pipeline transportation mode has been identified based on this research as the most cost-effective.

## 5.4 Recommendations

Issues such as time, safety, cost, reliability, speed and capabilities need to be considered for a transport system to be effective and efficient. Transport cost goes a long way to determine the price at which the end-user will purchase a product. However, for this study, cost and time was the major basis for comparism, therefore the following under-listed recommendations is needed to improve on the available system.

(i) The available pipeline transport should be adequately utilized for the distribution of petroleum products and more pipeline network should be constructed to link major cities across the country for easy distribution.

(ii) Where pipeline transport network is yet to get to, rail transport can be used as an alternative mode because it is relatively cheaper in terms of transport cost compared to road while road transport will complement rail and pipeline transport and more operational infrastructure such as tanks, wagons and locomotives should be made available for rail transport for effective distribution.

(iii) Sufficient security personnel should be employed to secure pipeline to reduce the major challenge of pipeline transport which is vandalization. This will create jobs and reduce unemployment for youths. The use of computers and communication technologies to monitor and control pipeline operations should be encouraged. The distribution of the products to non-registered marketers should be monitored adequately by the staff of PPMC.

(iv) More petroleum depots should be made available at strategic locations across the northern states as an aid to reduce pressure on the refinery for easy distribution at a minimized cost and to meet up with the increasing demand for petroleum

products in time. The incorporation of Ullman's theory of spatial interaction may be useful.

(v) Petroleum product road tankers should be involved for relatively short distance within cities, for example, from available depot to the selling points (filling stations), where consumers will have easy access at a minimized cost and roads should be properly maintained to aid fast and ease distribution of the products.

(vi) Education plays a very important role in the performance and attitudes of tanker drivers on the road. Tanker drivers should be trained and re-trained in Transport Technology Centre of NITT to better their driving skills and attitudes on the road.

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## Appendix 1

## QUESTIONNAIRE

## A COMAPARATIVE ANALYSIS OF THE COST-EFFECTIVENESS OF PETROLEUM PRODUCT HAULAGE FROM KADUNA REFINERY AND PETRO-CHEMICAL COMPANY BY ROAD, RAIL AND PIPELINE

Dear Sir,

This questionnaire is designed to obtain information for a research study on the above topic undertaking by Obasanjo, Obafemi Thompson, a Masters Degree student of Transport Management, Department of Geography, Ahmadu Bello University, Zaria.

The objective for the administration of this questionnaire is to identify the destination, cost and challenges of the petroleum product hauling from KRPC by tanker drivers.

I solicit your support to provide adequate and accurate information to the questions as all information provided will be treated in utmost confidence.

Thank you.

### SECTION A – SOCIO ECONOMIC CHARACTERISTICS

1. **Sex:** Male ( ) Female ( )
2. **Age:** 18-22 years ( ), 23-27 years ( ), 27-32 years ( ), 33-37 years ( ), 37-42 years ( ) 43- 47 ( ) 47-52 ( ) 53 and above ( )
3. **Marital Status:** Married ( ), Single ( ), Divorced ( )
4. **Educational Status:** Non Formal Education ( ) Primary Education ( ) Secondary Education ( ) Tertiary Education ( ) Others, please specify.....
5. **Do you work for any organization:** Yes ( ) No ( )
6. **If Yes, Name of Organisation**
   ……...
7. **How long have you been working?** 1-5years ( ), 6-10 years ( ), 11-15 years ( ),16-20years ( ), 21-25 years ( ), 25-30 years ( )
8. **Income per month:** □20,000 - □50,000 ( ), □50,000 – □100,000 ( ), □100,000-□200,000 ( ), □200,000- □300,000 ( ), □300,000-□400,000 ( ), □400,000 - □500,000 ( ), Above □500,000 ( )

### SECTION B – MOVEMENT OF PETROLEUM BY ROAD

9. Where are you moving this petroleum product to (destination)?
   Zaria ( ) Funtua ( ) Kafanchan ( ) Kano ( ) Gusau ( ) Kaura Namoda ( ) Bauchi ( ) Nguru ( )

   Jos ( ) Minna ( )

10. How many days does it take you to get to your destination?

a. 1 ( ) b. 2 ( ) c. 3 ( ) d. 4 ( ) e. 5 & above ( )

11. How often do you travel to your destination?

a. Every day ( ) b. Every week ( ) c. Once/twice a month ( ) d. Once/twice a quarter ( ) e. Once /twice a year ( )

12. How many litres do you move?

a. 11,000 ( ) b. 33,000 ( )

13. How much does it take to transport this petroleum product to your destination?

a. ₦10,000 – ₦50,000 ( ) b. ₦50,001- ₦100,000 ( ) c. ₦100,001 – ₦150,000 ( )
d. ₦150, 001 – ₦200, 000 ( ) e. ₦200, 001 & above ( )

15. Are you faced with any challenge while moving this petroleum product to your destination?

a. Yes ( ) b. No ( )

16. If Yes, rank the under listed problems in order of main concern from 1 to 7.

| **Problems** | **Rank 1** | **Rank 2** | **Rank 3** | **Rank 4** | **Rank 5** | **Rank 6** | **Rank 7** |
|---|---|---|---|---|---|---|---|
| Bad roads | | | | | | | |
| Theft/Robbery | | | | | | | |
| Accident | | | | | | | |
| Traffic congestion | | | | | | | |
| Mechanical problem | | | | | | | |
| Delays at police and customs check points | | | | | | | |
| Short delivery due to evaporation | | | | | | | |
| Inter-state revenue task personnel | | | | | | | |
| Delay in salary | | | | | | | |
| Delay in off-loading | | | | | | | |

17. How often do you encounter challenges in moving petroleum products to their destination?

a. Always ( ) b. Often ( ) c. Rarely ( ) d. I can't say ( )

18. In your view, how safe is the transportation of petroleum product using road transport (tankers)

a. Very safe ( ) b. Safe ( ) c. Not Safe ( ) d. I can't say ( )