OPTIMIZING THE COST OF TRANSPORTING MAJOR PETROLEUM PRODUCTS THROUGH PIPELINE BY THE NIGERIAN NATIONAL PETROLEUM CORPORATION (NNPC) IN THE DOWNSTREAM SECTOR.

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A THESIS SUBMITTED TO POSTGRADUATE SCHOOL, THE DEPARTMENT OF MATHEMATICS, FACULTY OF SCIENCE, NIGERIAN DEFENCE ACADEMY, KADUNA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE (M.Sc.) IN APPLIED MATHEMATICS

AUGUST, 2017

DECLARATION

I, declare that this thesis entitled "Optimizing the Cost of Transporting Major Petroleum Products through Pipeline by the Nigerian National Petroleum Corporation (NNPC) in the Downstream Sector" has been carried out by me in the department of Mathematics. The information derived from the literature has been dully acknowledged in the text and a list of references provided. No part of this thesis was presented for another degree or diploma at this or any institution. If however, it is discovered in future that any part of the work does not represent my personal idea, or has been plagiarized, I shall be liable to a penalty, which may include withdrawal of my certificate with the available regulation.

Isinguzo Ubaeze Justin__	_____	_____
NDA/PGS/FS/M/1854/14	Signature	Date

CERTIFICATION

I hereby certify that this thesis entitled "Optimizing the Cost of Transporting Major Petroleum Products Through Pipeline by the Nigerian National Petroleum Corporation (NNPC) in the Downstream Sector" by Isinguzo Ubaeze Justin (NDA/PGS/FS/M/1854/14), was carried out under my supervision for the award of Master of Science, in the department of Mathematics, Nigerian Defence Academy, Nigeria. However, the author is responsible for the content of the work.

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APPROVAL PAGE

This thesis entitled “Optimizing the Cost of Transporting Major Petroleum Products through Pipeline by the Nigerian National Petroleum Corporation (NNPC) in the Downstream Sector” by Isinguzo Ubaeze Justin (NDA/PGS/FS/M/1854/14) meets the regulations governing the award of the degree of Master of Science Mathematics of Nigerian Defence Academy, Kaduna, and is approved for its contribution to knowledge and literary presentation.

_____ _____

Dr. B. Ali Date

H.O.D

Mathematics Department

_____ _____

External Examiner Date

_____ _____

Prof. A. O. Ahmed Date

DEDICATION

To my late Grand-Mother Justina Onwuyiriuwa.

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It is expedient to show gratitude in all things and most especially when it is due. My most profound gratitude is unto God who has kept me. By sustaining me and showing me mercy. God he has shown his unbridled faith in me this entire period even when I have been undeserving. Thank you Sweet Jesus for the strength, direction and guidance in writing this project I am grateful.

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ABSTRACT

One major problem in Nigeria is the persistent scarcity and inequitable distribution of petroleum products even with the establishment of three refineries, many storage depots and pipelines interconnecting them. This research work examines the situation in the petroleum downstream sector in order to determine the future demand, and produce an efficient and equitable distribution of three blends of petroleum products, namely; Premium motor spirit (PMS) House Hold Kerosene (HHK) and Automotive Gas Oil (AGO). For a comprehensive analysis, three refineries and twenty two storage depots were considered because of their interconnections with pipelines. The demand from depots and supply from the three refineries were forecasted using the single exponential smoothening technique and solved using the Microsoft Excel Data Analysis tool pack. The result of the forecast was used to formulate a mathematical model, which was solved using "PYOMO" Optimization software, to obtain the optimal transportation cost of transporting the products from the refineries to various depots across the nation through pipeline system of transportation.

CHAPTER ONE: INTRODUCTION

1.1 Background of Study

Nigeria's economy is dominated by the oil and gas sector. In 2004, this sector accounted for about 80% of all government revenue, 90-95% of export revenues, and over 90% of foreign exchange earnings (Aluko, 2004).The country is Africa's leading oil producer and at a global level, ranks among the top 10 oil producers (Ojogbo, 1999). The Nigerian National Petroleum Corporation (NNPC) is the state oil corporation which was established on April 1, 1977. In addition to its exploration activities, the Corporation was given powers and operational interests in refining and transportation of petrochemicals and products as well as marketing. Between 1978 and 1989, NNPC constructed refineries in Warri, Kaduna and Port Harcourt and took over the 35,000-barrel Shell Refinery established in Port Harcourt in 1965 (NNPC, 2015a). Pipeline transportation is the major means of transporting petroleum products in Nigeria. Much attention has not been given to it because its operations and services are not in the hands of private individuals and companies. Hence, everything about pipeline transportation in Nigeria is strictly in the hands of the Federal Government (Agbaeze, 2002).

According to Kupoliyi (2000), pipeline has been in use for transporting materials for centuries. He further stated that, pipelines are used for distributing potable water in urban areas. Though the pipelines network for the transportation and distribution of water in urban areas are usually short, they use the same basic principles as the ones for distributing petroleum products. Olakunori (2000) reported that petroleum pipelines made recent discoveries into Nigeria, where the products pumped through the Nigeria pipelines include:

- Premium motor spirit (PMS) also known as petrol;
- Automotive Gas Oil (AGO), known as diesel; and
- Household Kerosene, (HHK).

In march,1988 the NNPC was reorganized for the purpose of proper capitalization and commercialization, The subsidiary created was the Pipelines And Product Marketing Company (PPMC).The creation of PPMC is perhaps the most significant event of the 1988 in the reorganization of NNPC, because the establishment of this subsidiary is directly responsible for the comparative ease with which petroleum products are sourced and distributed to all parts of the country, at a uniform price: a phenomenon which Nigerians have come to take for granted. NNPC (2015) introduced the pipelines and product marketing company (PPMC) limited, as a subsidiary of the Nigerian National Petroleum Corporation (NNPC) which ensures, among other things, the availability of petroleum products to sustain our industries, run automobiles and for domestic cooking.

Before 1965 when Nigeria's first petroleum refinery was established in port-Harcourt by shell and British Petroleum (BP), petroleum products used in the country were imported. The importation of petroleum products continued even after the refurbishing of the old Port Harcourt Refinery, which was damaged during the Nigerian civil war. For quite some time, marketers and consumers of petroleum products in Nigeria depended on external sources for the products. However, the story is different. The marketing companies (major and independent) now distribute most of the products to the end users after receiving supply from this NNPC subsidiary. NNPC has three refineries, at Kaduna, Port Harcourt and Warri. The three refineries have a combined installed capacity of 445,000 bpd. A comprehensive network of pipelines and Depots strategically located throughout Nigeria links these refineries. NNPC, through its subsidiary – the Pipelines and Products Marketing Company (PPMC), supplies only to bulk customers, who in turn supply the products ranging from gasoline (PMS), house hold kerosene and jet fuel to diesel, fuel oil and liquefied petroleum gas to millions of customers across the country (NNPC, 2015).

PPMC receives crude oil from the NNPC unit called the National Petroleum Investments Management Services (NAPIMS). PPMC then supplies the crude oil to the NNPC local refineries. However, petroleum products are sometimes imported to supplement local production when the local refineries are unable to process enough for the country's needs. Petroleum products either imported or refined locally are received by the PPMC through import jetties and pipelines and distributed through pipelines to depots strategically located all over the country from where

petroleum tankers lift the products to designated retail outlets. There is also provision for using the rail system to move from some of the PPMC depots.

In past years the cost of transporting these products through the pipeline network annually has amounted to billions of dollars. The production and distribution of petroleum products in Nigeria' downstream sector is an important factor in her domestic economy. From 1970 to 2017, the nation has invested substantially in refineries, storage depots and pipelines. The total pipeline network is about 4500Km (PPMC, 1994a). Unfortunately, within the past few years, the supply of these petroleum product blends to storage depots and then to consumers have not been enough to meet the increasing demand. The areas of demand include: Domestic sector, Industrial sector, Transport and Agricultural sectors (PPMC, 1994b).

The factors that influence the consumption of major petroleum products both for transport and domestic activities have received a great deal of attention since the first oil *crisis* in the early 1970s (Espey, 1996). In addition, to determine the key influence on the consumption of petrol and other products like House Hold Kerosene (HHK) and Automotive Gas Oil (AGO), many studies examining fuel demand have been undertaken to predict future demand (Banaszak *et al.* 1999; Murat and Ceylan, 2006; Ediger and Akar, 2007). Proper schedule of the distribution through pipeline networks can facilitate the economic integration of refinery locations and storage depots for easy shipment of the products from refineries to depot locations and then to consumers at minimum delivery cost (Eke and Enibe, 2007). The refineries are:

- **Port-Harcourt Refining Company(PHRC) Limited** situated in Port Harcourt, Rivers state,
- **Warri Refinery and Petrochemical Company (WRPC) Limited** situated in Warri, Delta state and
- **Kaduna Refinery and Petrochemical Company (KRPC) Limited** situated in Kaduna, Kaduna state;

The storage depots are located in **Aba, Enugu, Makurdi, Yola, Benin, Ore, Mosimi, Atlas-Cove** and **Satellite** both in Lagos, **Ibadan, Ilorin, Suleja, Minna, Kaduna, Jos, Gombe, Maiduguri, Kano, Port-Harcourt, Warri, Calabar** and **Gusau.**

1.2 Statement of the Problem

In this study, we attempt to proffer solutions to the inadequate petroleum products available to the final consumer as a result of inappropriate distribution mechanism. In this regard, we use the single exponential smoothening method of forecasting to make a one year forecast on the demand of the three major products (Premium motor spirit (PMS), House Hold Kerosene (HHK) and Automotive Gas Oil (AGO)) in the downstream sector of the petroleum industry in Nigeria. In addition, we formulate a linear programming model that would minimize the future cost of transporting major products from the three Nigerian refineries to the twenty two depots in the country through pipelines. The problem so formulated is solved using the data analysis pack in Microsoft Excel and Pyomo software in Python package for the forecast and linear programming problem respectively.

1.3 Aim of the Study

The objective of this study is to make a one year forecast of the demand and supply of major petroleum products in the country and then develop a linear programming model that will minimize the cost of transporting these products from the refineries to various depots across the nation through pipeline.

1.4 Specific Objectives of the Study

The specific objective of this research include, to;

I. make a one year forecast of the demand and supply of major petroleum products (PMS, HHK and AGO) in the downstream sector of the petroleum by using the exponential smoothening method with the damping factor of 0.01
II. Develop a linear programming model that will minimize the cost of transporting these products from refineries to the 22 depots across the nation through pipeline.
III. Produce a future cost that will be incurred in transporting these products through pipeline.

1.4 Scope of the Study

This work covers the use of linear programming model to minimize the future cost of transporting the three products PMS, HHK and AGO from the three major refineries to the twenty two depots in Nigeria through pipeline transportation. The future demand is predicted by making a forecast of

the previous years' demand of all the depots in the country by using the exponential smoothening method with alpha at 0.99.

1.5 Expected Findings

At the end of the research, we should be able to:

I. Determine a mathematical model that will predict the future cost of transporting finished products from refineries to depots.
II. Ascertain or predict the need to switch supply route by depots should the demand of the depots increase or decrease.
III. Deduce or predict the amount to be spent by PPMC in pipeline transportation of PMS, HHK and AGO
IV. Predict the need of a new refinery on the long run.

1.6 Expected Contribution to Knowledge

At the end of this research work, we should be able to;

I. Forecast the future yearly demand of the three petroleum products (PMS, HHK and AGO) using exponential smoothening method;
II. Develop a mathematical model that will minimize the transportation cost of distributing these product from the refineries to the depots.
III. Predict the yearly consumption of the products by each state which in turn determines the yearly demand for products at each depots.

1.7 Data and Methodology

The aim of this research is achieved from the data collected from the planning and budget monitoring department (PBMD) of the headquarters of Nigerian National Petroleum Cooperation (NNPC) located in Abuja. The data collected is used to produce a one year forecast of future demand using the simple exponential smoothening method and then the result from the forecast is formulated as a linear programming model that minimizes the future cost of transporting major products from the three major refineries in Nigeria to depots across the country.

1.8 Organization of the rest of the work.

Chapter one introduces the thesis by starting with the background of the study, statement of the problem, its aim and objectives and as well as the scope and expected findings.

Chapter two deals with the review of relevant literature of the study and this review focuses on method that have been adopted by previous researchers and limitations of their methods, as well as a discussion of the results from previous studies.

The third chapter discusses vividly, the mathematical and statistical methods and procedures used in the analysis of the monthly data for some of the petroleum product demand in Nigeria. The fourth chapter also deals with the analysis of quarterly data for some of the petroleum product demand in Nigeria over 8 year period comprising of data from January 2007 to November 2015 that is 32 quarters. The interpretations and discussions are also presented in this chapter. The last chapter covers conclusion and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Historical Development of Petroleum Pipeline Transportation.

Henry and Miller (1977) stated that the first pump operated petroleum pipelines were built in the United States of America in 1863 and the first petroleum product lines appeared there in the 1920s. According to them, by 1960, the network of petroleum pipelines in the United States totaled over 300,000 kilometers. The network has been expanding annually, as petroleum gains more and more prominence as a source of energy. Petroleum pipeline was first introduced into the Nigeria market in 1907 by Mobil. Mobil imported into the country the "sunflower" brand of tinned household kerosene (HHK) coloured blue. This was sold mainly in the big towns, such as Lagos, Ibadan, Kano, Benin city and Enugu for local consumption. It was then that petroleum refinery in Nigeria was established in 1965 in Port Harcourt by British petroleum and shell (PPMC 1996).

As a result of the acceptance of the recommendations of the Oputa panel of Enquiry of 1975, the Federal Government of Nigeria took over the importation of petroleum products into the country through the Nigeria National petroleum corporation (NNPC). In addition, the federal government began work on the construction of refinery and storage facilities and pipeline to link these storage centres. Ndu (1998) stated that, the 125,000 barrels per day capacity of Warri refinery was constructed and commissioned in 1979. Government commitment to the pursuit of self- sufficiency in refined petroleum products led to additional investment in the expansion of Old Port Harcourt refinery to 60,000 barrels per day. The construction and commissioning of the new 150,000 barrels per day capacity port Harcourt refinery in 1989, and the phase 111 pipeline and depots interlink in 1995 (PPMC,1998). The pipeline phase 111 project was embarked upon in order to provide an interlink pipelines and depots projects were concluded between 1979 and 1980. Lack of interlink facilities did not allow consumers to enjoy the full benefits of the project. Hence, the prime objective that motivated the persecution of the pipeline system into national grid of product pipeline, with the view of improving the network's capacity, operational flexibility and reliability. The expansion of the pipelines network together with the construction of storage facilities were thus aimed at satisfying a minimum of 45 days local demand for normal operation up to the year 2010 (Olakunori: 2000). A summary of the Nigeria petroleum products pipeline network is listed below as noted in PPMC (2002), where The Nigerian pipeline network is classified into five basic systems, namely A,B,C,D,E and is managed by NNPC through its subsidiary – the Pipeline and Production Marketing Company (PPMC) limited.

System 2A	Warri – Benin – Ore – Mosimi
System 2AX	Auchi – Benin
System 2B	(a) Atlas cove- Mosimi- Ibadan- Ilorin
	(b) Mosimi – Satellite (Ejigbo in Lagos)
	(c) Mosimi – Ikeja
System 2C	Escravos — Wari- Kaduna (crude oil)
System 2CX	(a) Enugu – Auchi (Interconnection)
	(b) Auchi — suleja - Kaduna
	(c) Suleja- Minna
System 2DX	Jos – Gombe
System 2E	Port Harcourt —Aba —Enugu- Makurdi

Source: Pipeline Interlink and Distribution of Refined Petroleum Products in Nigeria, Lagos: PPMC (2002).

Forecasting of energy demand in emerging markets is one of the most important policy tools used by decision makers all over the world. In Turkey, most of the early studies used include various forms of econometric modeling. However, since the estimated economic and demographic parameters usually deviate from the realizations, time-series forecasting appears to give better results. Volkan et al. (2007), used the Autoregressive Integrated Moving Average (ARIMA) and seasonal ARIMA (SARIMA) methods to estimate the future primary energy demand of Turkey from 2005 to 2020. The ARIMA forecasting of the total primary energy demand appears to be more reliable than the summation of the individual forecasts. The results have shown that the average annual growth rates of individual energy sources and total primary energy will decrease in all cases except wood and animal–plant remains which will have negative growth rates. The decrease in the rate of energy demand may be interpreted that the energy intensity peak will be achieved in the coming decades. Another interpretation is that any decrease in energy demand will slow down the economic growth during the forecasted period. Rates of changes and reserves in

the fossil fuels indicate that inter-fuel substitution should be made leading to a best mix of the country's energy system.

A study by Kumar and Jain (2009) applies three time series models, namely, Grey-Markov model, Grey-Model with rolling mechanism, and singular spectrum analysis (SSA) to forecast the consumption of conventional energy in India. Grey-Markov model was employed to forecast crude – petroleum consumption while Grey-Model with rolling mechanism was used to forecast coal and electricity (in utilities) consumption while SSA was used to predict natural gas consumption. The models for each time series were selected by carefully examining the structure of the individual time series. The mean absolute percentage errors (MAPE) for two out of sample forecasts were obtained as follows: 1.6% for crude-petroleum, 3.5% for coal, 3.4% for electricity and 3.4% for natural gas consumption. For two out of sample forecasts, the prediction accuracy for coal consumption was 97.9%, 95.4% while for electricity consumption the prediction accuracy was 96.9%, 95.1%. Similarly, the prediction accuracy for crude-petroleum consumption was found to be 99.2%, 97.6% while for natural gas consumption these values were 98.6%, 94.5%. The results obtained have also been compared with those of Planning Commission of India's projection. The comparison clearly points to the enormous potential that these time series models possess in energy consumption forecasting and can be considered as a viable alternative.

Lon-Mu (2006) studied the dynamic relationships between US gasoline prices, crude oil prices, and the stock of gasoline. Using monthly data between January 1973 and December 1987, they found that the US gasoline price is mainly influenced by the price of crude oil. The stock of gasoline has little or no influence on the price of gasoline during the period before the second energy crisis, and seems to have some influence during the period after. He found out that the dynamic relationship between the prices of gasoline and crude oil changes over time, shifting from a longer lag response to a shorter lag response. These models were estimated using estimation procedure with and without outlier adjustment. For model estimation with outlier adjustment, an iterative procedure for the joint estimation of model parameters and outlier effects is employed. The forecasting performance of these models is carefully examined. For the purpose of illustration, Lon-Mu (2006) also analyzes these time series using classical white-noise regression models. The results show the importance of using appropriate time-series methods in modeling and forecasting when the data are serially correlated.

The oil industry has used decline curve analysis with limited success in estimating crude oil reserves and in predicting future behaviour of oil and gas wells. Ayeni et al (2001), therefore, explored the possibility of using the Autoregressive Integrated Moving Average (ARIMA) technique in forecasting and estimating crude oil reserves. The authors compared the approach with the traditional decline method using real oil production data from twelve (12) oil wells in South Louisiana. The Box and Jenkins methodology was used to develop forecast functions for the twelve wells under study. These forecast functions were used to predict future oil productions. The forecast values generated were then used to determine the remaining crude oil reserves for each well. The accuracy of the forecasts relative to the actual values for both ARIMA and decline curve methods is determined by various statistical error analyses. The conditions, under which one method gives better results than the other, were fully investigated. In almost all the cases considered, the ARIMA method is found to perform better than the decline curve method.

The work by (Shubin, 2012) applied the theory of Bayesian linear regression and Markov Chain Monte Carlo method (MCMC) to establish a demand-forecast model of petrol and diesel. In their study a final comparison between the predicted results from autoregressive integrated moving average models (ARIMA) and others is made to assess our task. The use of wavelet-neural-network based forecast model by (Li, 2009) was developed for energy demand in China. Their simulation result reveals that the nonlinear forecasting model is more reasonable and has higher precision than other multiple regressions models. Many traditional methods analysis have been used to forecast fuel demand. Among these methods are time series, regression, econometric, ARIMA. Computing techniques such as fuzzy logic, genetic algorithm, and neural networks are being extensively used for demand side management (Suganthia, 2011). In this study exponential smoothening model was used in forecasting PMS, AGO, AND HHK consumption in Nigeria for the following year. Secondary data was obtained from the planning and budget monitoring department (PBMD) of the headquarters of Nigerian National Petroleum Cooperation (NNPC).

The transportation problem was formalized by the French mathematician Gaspard Monge in 1781. Major advances were made in the field during World War II by the Soviet/Russian mathematician and economist Leonid Kantorovich. Consequently, the problem as it is now stated is sometimes known as the Monge-Kantorovich transportation problem (Wikipedia. 2016). Kantorovich (1942), published a paper on continuous version of the problem and later with Gavurian, and applied study

of the capacitated transportation problem (Kantorovich and Gavurin, 1949). Many scientific disciplines have contributed toward analyzing problems associated with the transportation problem, including operation research, economics, engineering, Geographic Information Science and geography. It is explored extensively in the mathematical programming and engineering literatures. Sometimes referred to as the facility location and allocation problem, the Transportation optimization problem can be modeled as a large-scale mixed integer linear programming problem.

The origin of transportation was first presented by Hitchcock, (1941), who presented a study entitled "The Distribution of a Product from Several sources to numerous Localities". This presentation is considered to be the first important contribution to the solution of transportation problems. Koopmans, (1974), presented an independent study, not related to Hitchcock"s, and called "Optimum Utilization of the Transportation System". These two contributions helped in the development of transportation methods which involve a number of shipping sources and a number of destinations. The transportation problem, received this name because many of its applications involve determining how to optimally transport goods.

However it could be solved for optimally as an answer to complex business problem only in 1951, when George B. Dantzig applied the concept of Linear Programming in solving the Transportation models. Dantizig, (1963), then uses the simplex method on transportation problem as the primal simplex transportation method.

Stringer and Haley (1957) developed a method of solution using a mechanical analogue. May be the first algorithm to find an optimal solution for the incapacitated transportation problem was that of Eroymson and Ray (1966). They assumed that each of the unit production cost functions has a fixed charge form. But they remark that their branch-and - bound method can be extended to the case in which each of these functions is concave and consists of several linear Segments. And each unit transportation cost function is linear.

Sharp.et.al (1970) developed an algorithm for reaching an optimal solution to the production-transportation problem for the convex case. The algorithm utilizes the decomposition approach it iterates between a linear programming transportation problem which allocates previously set plant production quantities to various markets and a routine which optimally sets plant production

quantities to equate total marginal production costs, including a shadow price representing a relative location cost determined from the transportation problem.

Williams(1962) applied the decomposition principle of Dantizig and Wolf to the solution of the Hitchcock transportation problem and to several generalizations of it. In this generalizations, the case in which the costs are piecewise linear convex functions is included. He decomposed the problem and reduced to a strictly linear program. In addition he argued that the two problems are the same by a theorem that he called the reduction theorem. The algorithm given by him, to solve the problem, is a variation of the simplex method with "generalized pricing operation". It ignores the integer solution property of the transportation problem so that some problems of not strictly transportation type, and for which the integer solution property may not hold be solved.

Shetty(1959) also formulated an algorithm to solve transportation problems taking nonlinear costs. He considered the case when a convex production cost is included at each supply center besides the linear transportation cost. Some of the approaches used to solve the concave transportation problem are presented as follows. The branch and bound algorithm approach is based on using a convex approximation to the concave cost functions. It is equivalent to the solution of a finite sequence of transportation problems. The algorithm was developed as a particular case of the simplified algorithm for minimizing separable concave functions over linear polyhedral as Falk and Soland.

Soland (1971) presented a branch and bound algorithm to solve concave separable transportation problem which he called the "Simplified algorithm" in comparison with similar algorithm given by Falk and himself in (1969). The algorithm reduces the problem to a sequence of linear transportation problem with the same constraint set as the original problem.

Caputo. et. Al (2006). presented a methodology for optimally planning long-haul road transport activities through proper aggregation of customer orders in separate full-truckload or less-than-truckload shipments in order to minimize total transportation costs. They have demonstrated that evolutionary computation techniques may be effective in tactical planning of transportation activities. The model shows that substantial savings on overall transportation cost may be achieved adopting the methodology in a real life scenario.

Roy and Gelders (1980) solved a real life distribution problem of a liquid bottled product through a 3-stage logistic system; the stages of the system are plant-depot, depot-distributor and distributor-dealer. They modelled the customer allocation, depot location and transportation problem as a 0-1 integer programming model with the objective function of minimization of the fleet operating costs, the depot setup costs, and delivery costs subject to supply constraints, demand constraints, truck load capacity constraints, and driver hours constraints. The problem was solved optimally by branch and bound, and Langrangian relaxation.

Tzeng et al. (1995) solved the problem of how to distribute and transport the imported Coal to each of the power plants on time in the required amounts and at the required18 quality under conditions of stable and supply with least delay. They formulated a LP that Minimizes the cost of transportation subject to supply constraints, demand constraints, vessel constraints and handling constraints of the ports. The model was solved to yield optimum results, which is then used as input to a decision support system that help manage the coal allocation, voyage scheduling, and dynamic fleet assignment.

Saumis et al. (1991) considered a problem of preparing a minimum cost transportation plan by simultaneously solving following two sub-problem: first the assignment of units available at a series of origins to satisfy demand at a series of destinations and second, the design of vehicle tours to transport these units, when the vehicles have to be brought back to their departure point. The cost minimization mathematical model was constructed, which is converted into a relaxation total distance minimization, then finally decomposed to network problems, a full vehicle problem, and an empty vehicle problem. The problems were solved by tour construction and improvement procedures. This approach allows large problems to be solved quickly, and solutions to large problems to be solved quickly, and solutions to large test problems have been shown to be 1% 0r 2% from the optimum.

Klingman and Russell (1975) have developed an efficient procedure for solving transportation problems with additional linear constraints. Their method exploits the topological properties of basis trees within a generalized upper bound framework.

Algorithms for the capacitated case have been presented by Davis and Ray (1969), Ellwein (1970), Gray (1970), Marks,(1969), and SA (1969). In all of these the cost functions are assumed to be

linear and the production cost is linear where ever the production is and zero where not. Ellwein's technique allows the easy incorporation of configuration constraints that restrict the allowable combinations of open plants and generalization of the production.

These problems have been studied extensively by many authors and have found applications in such diverse fields as geometry, fluid mechanics, Statistics, economics, shape recognition, inequalities and meteorology. In this thesis we seek to apply the exponential smoothening technique for producing a forecast and then apply the simplex algorithm to produce the optimal cost of transporting finished petroleum products through pipeline.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Forecasting Technique used

Secondary data was obtained from the planning and budget monitoring department (PBMD) of the headquarters of Nigerian National Petroleum Cooperation (NNPC). The simplest of the exponential smoothing, called "simple exponential smoothing" (SES) or "single exponential smoothing", which is suitable for forecasting data with no trend or seasonal pattern, although the mean of the data may be changing slowly over time, is used in this study to forecast future yearly consumption of PMS, AGO, and HHK in Nigeria. The concept behind simple exponential smoothing is attaching larger weights to more recent observations than to observations from the distant past as shown in equation 3.1 and table 3.1 where the weight is α and Y_t is the observation at the current year, t. Forecasts are calculated using weighted averages where the weights decrease exponentially as observations come from further in the past, the smallest weights are associated with the oldest observations.

$$L_t = \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + \alpha(1-\alpha)^2 Y_{t-2} +, \ldots \ldots \quad (3.1)$$

where $0 \leq \alpha \leq 1$ is the smoothing parameter. The one-step-ahead forecast for time $t+1$ is a weighted average of all the observations in the series $Y_1, \ldots, Y_t$. The rate at which the weights decrease is controlled by the parameter α Table 3.1 shows the weights attached to observations for four different values of α when forecasting using simple exponential smoothing.

Table 3.1: *weight distribution pattern for observations*

OBSERVATION	$\alpha = 0.2$	$\alpha = 0.4$	$\alpha = 0.6$	$\alpha = 0.8$
Y_t	0.2	0.4	0.6	0.8
Y_{t-1}	0.16	0.24	0.24	0.16
Y_{t-2}	0.128	0.144	0.096	0.032
Y_{t-3}	0.1024	0.0864	0.0384	0.0064
Y_{t-4}	$(0.2)(0.8)^4$	$(0.4)(0.6)^4$	$(0.6)(0.4)^4$	$(0.8)(0.2)^4$

The forecast at time $t+1$ is equal to a weighted average between the most recent observation Y_t and the most recent forecast $\hat{Y}_{t|t-1}$

$$\hat{Y}_{t+1|t} = \alpha Y_t + (1-\alpha)\hat{Y}_{t|t-1} \tag{3.2}$$

for $t = 1, \dots, T$, where $0 \leq \alpha \leq 1$ is the smoothing parameter.

3.2 Forecast Model

In formulating the model, we first make a one year forecast on the future demand (D_j) and supply (S_i) using Microsoft Excel data analysis software to run the single exponential smoothening technique of forecasting. This model is hence given by;

$$\ell_t = \alpha Y_t + (1-\alpha)\ell_{t-1} \tag{3.3}$$

Where,

ℓ_t = Revised Estimate of the demand (D_j) of depots or supply (S_i) from refineries at time "t"
$\boldsymbol{\alpha}$ = Weight placed on current time series value ***(Smoothening constant)***
$\boldsymbol{y_t}$ = Current time series value (year)

$(\mathbf{1}-\boldsymbol{\alpha})$ = Weight placed on last estimate for the demand (D_j) of depots or supply (S_i) from refineries (***Damping factor).***

ℓ_{t-1} = Last estimate for the demand (D_j) of depots or supply (S_i) from refineries.
The above model is applied with a smoothening constant (α) of 0.99 and a damping factor $(1-\alpha)$ of 0.01. Hence in this study, the process starts from 2007 where the first forecast of Y_{2007} is denoted by ℓ_0.

$$\hat{Y}_t = \alpha Y_{t-1} + (1-\alpha)\hat{Y}_{t-1} \tag{3.4}$$

for $t = 2008, 2009, \dots, 2016$.

3.3 Mathematical Model of Petroleum Distribution

The mathematical model of transporting the three products of PMS, HHK and AGO from the three refineries to the 22 depots through pipeline network is given by;

Model For PMS

$$Minimize\ Z = \sum_{i=1}^{3}\sum_{j=1}^{22} P_{ij}\, C_{ij} \tag{3.5}$$

Subject to the constraints

$$\sum_{j=1}^{22} P_{ij} \leq S_i \ \ all\ source\ nodes\ i \tag{3.6}$$

$$i = 1,2,\ldots.,m \ \ where\ \ m = 3$$

$$\sum_{i=1}^{3} P_{ij} \geq D_j \ \ all\ source\ nodes\ j \tag{3.7}$$

$$j = 1,2,\ldots.,n \ \ where\ \ n = 22$$

$$P_{ij} \geq 0, \text{and integral.} \tag{3.8}$$

Model For HHK

$$Minimize\ Z = \sum_{i=1}^{3}\sum_{j=1}^{22} C_{ij}\, H_{ij} \tag{3.9}$$

Subject to the constriants

$$\sum_{j=1}^{22} H_{ij} \leq S_i \ \ all\ source\ nodes\ i \tag{3.10}$$

$$i = 1,2,\ldots.,m \ \ where\ \ m = 3$$

$$\sum_{i=1}^{3} H_{ij} \geq D_j \ \ all\ source\ nodes\ j \tag{3.11}$$

$$j = 1,2,\ldots.,n \ \ where\ \ n = 22$$

$$H_{ij} \geq 0, \text{and integral.} \tag{3.12}$$

Model For AGO

$$Minimize\ Z = \sum_{i=1}^{3}\sum_{j=1}^{22} C_{ij}\, A_{ij} \qquad (3.13)$$

Subject to the constriants

$$\sum_{j=1}^{22} A_{ij} \leq S_i \ \ all\ source\ nodes\ i \qquad (3.14)$$

$$i = 1,2,\ldots..,m \ \ where\ \ m = 3$$

$$\sum_{i=1}^{3} A_{ij} \geq D_j \ \ all\ source\ nodes\ j \qquad (3.15)$$

$$j = 1,2,\ldots..,n \ \ where\ \ n = 22$$

$$A_{ij} \geq 0, \text{and integral.} \qquad (3.16)$$

Where

P_{ij}, H_{ij} and A_{ij} represents quantity of PMS, HHK or AGO respectively transported from supply point i (refineries) at unit cost (C_{ij}) to demand point j (storage depots).

$\boldsymbol{C_{ij}}$ = Cost of transporting each unit (liter) product from supply point (refinery) $\boldsymbol{i}$ to demand point (depot) $\boldsymbol{j}$.

$\boldsymbol{S_i}$ = Supply point availability (quantity of products produced by the refinery)

$\boldsymbol{D_j}$ = Demand point requirement (quantity of product needed by the depot to satisfy the needs of its geographical location)

- The equations (3.5), (3.9) and (3.13) of the model are the objective functions which expresses the goal of each problem.
- Equations (3.6), (3.10) and (3.14) of the model are the supply availability. This indicates that the quantities of final blended products leaving the refineries (supply) must exceed the sum of the demands at all depots.
- Equations (3.7), (3.11) and (3.15) of the model are the demand requirement. The demand model indicates that the quantities of blended products leaving the refineries must satisfy the demands of storage depots.
- Equations (3.8), (3.12) and (3.16) of the model are the non-negativity constraint which explains that the quantity of each final blended product transported from refineries to the depots must be greater than or equal to zero.

The Table 3.2 below show the decision variables denoting respectively PMS, HHK and AGO supplied from the three refineries to the twenty two (22) storage depots in Nigeria.

Table 3.2: ***Decision Variables Denoting Supply from Refineries to Depots***

S/N(j)	REFINERY / DEPOTS	(i) 1	2	3
		PHRC	KRPC	WRPC
1	ABA	$X_{1,1}$	$X_{2,1}$	$X_{3,1}$
2	BENIN	$X_{1,2}$	$X_{2,2}$	$X_{3,2}$
3	CALABAR	$X_{1,3}$	$X_{2,3}$	$X_{3,3}$
4	ENUGU	$X_{1,4}$	$X_{2,4}$	$X_{3,4}$
5	GUSAU	$X_{1,5}$	$X_{2,5}$	$X_{3,5}$
6	GOMBE	$X_{1,6}$	$X_{2,6}$	$X_{3,6}$
7	IBADAN	$X_{1,7}$	$X_{2,7}$	$X_{3,7}$
8	ILORIN	$X_{1,8}$	$X_{2,8}$	$X_{3,8}$
9	JOS	$X_{1,9}$	$X_{2,9}$	$X_{3,9}$
10	KADUNA	$X_{1,10}$	$X_{2,10}$	$X_{3,10}$
11	KANO	$X_{1,11}$	$X_{2,11}$	$X_{3,11}$
12	ATLAS COVE	$X_{1,12}$	$X_{2,12}$	$X_{3,12}$
13	SATELLITE	$X_{1,13}$	$X_{2,13}$	$X_{3,13}$
14	MOSIMI	$X_{1,14}$	$X_{2,14}$	$X_{3,14}$
15	MAKURDI	$X_{1,15}$	$X_{2,15}$	$X_{3,15}$
16	MAIDUGURI	$X_{1,16}$	$X_{2,16}$	$X_{3,16}$
17	MINNA	$X_{1,17}$	$X_{2,17}$	$X_{3,17}$
18	ORE	$X_{1,18}$	$X_{2,18}$	$X_{3,18}$
19	PORT HARCOURT	$X_{1,19}$	$X_{2,19}$	$X_{3,19}$
20	SULEJA	$X_{1,20}$	$X_{2,20}$	$X_{3,20}$
21	WARRI	$X_{1,21}$	$X_{2,21}$	$X_{3,21}$
22	YOLA	$X_{1,22}$	$X_{2,22}$	$X_{3,22}$

CHAPTER FOUR: DATA ANALYSIS AND RESULTS

4.1 Findings of the Demand of Major Products in Nigeria.

This section examines the findings of the study, thus, forecasting the consumption of major petroleum products in Nigeria. The following sub-sessions present analysis and discuss the demand for these products in Nigeria.

4.2 Pattern of Products Demand/ Consumption

The following appendix 1, 2 and 3 represents the annual demand for PMS, AGO and HHK respectively by states for (2007-2014). The study used data collected within 7-year period: 2007 – 2014. The average yearly consumption levels were 7,758,562,000, 2,676,919,000, 1,039,074,000 litres for PMS, HHK and AGO respectively. The lowest quantity demanded for PMS occurred in 2009 with 6,876,577,000L sold while for HHK was in the year 2007 with 1,759,121,000L sold and that of ago was in the year 2014 with 551,338,000L sold. By comparison, it can be said that, in all cases (in terms of yearly demand), the demand for PMS has been higher than other major products. Possible reasons that may account for this observation is the growing emergence of private and passenger vehicles that use PMS. However there has been an increase in the demand for HHK as it is a major source of cooking fuel for an average Nigerian.

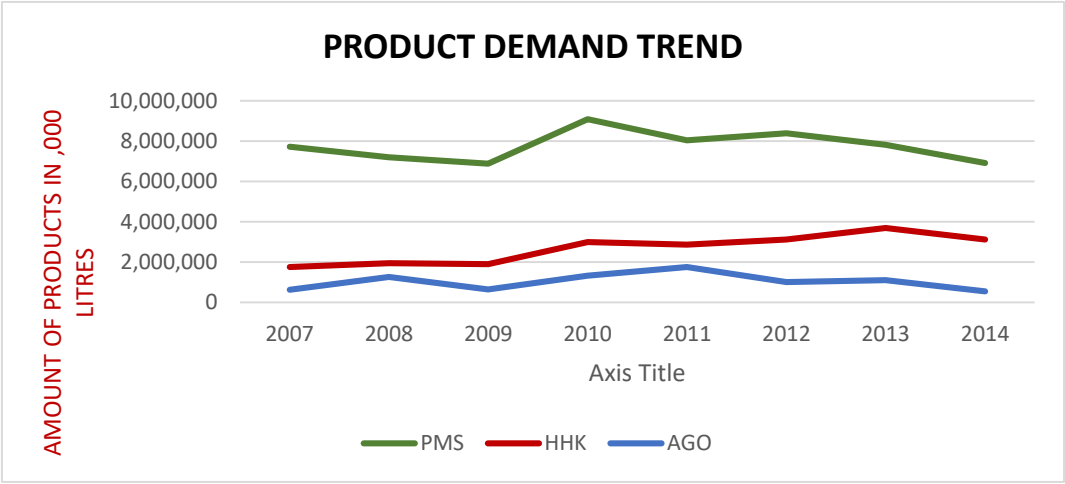

Figure 4.1: ***Showing the demand trend from 2007- 2014***

In addition, the irregularities in the demand for AGO could be justified with the fact that our major producing industries have not been consistent in production due to the economic crises accounted for in the country and the general fall in demand can be attributed to the zeal for clean energy and decline in the number of manufacturing companies .

Demands by depots.

Since the states are dependents on the individual depots located across the country, it can be observed that the various depots have catchment areas which are the states dependent on the depots close to them, as seen from the map below (fig 4.2), we can easily deduce the states that are dependent on the various depots located across the country.

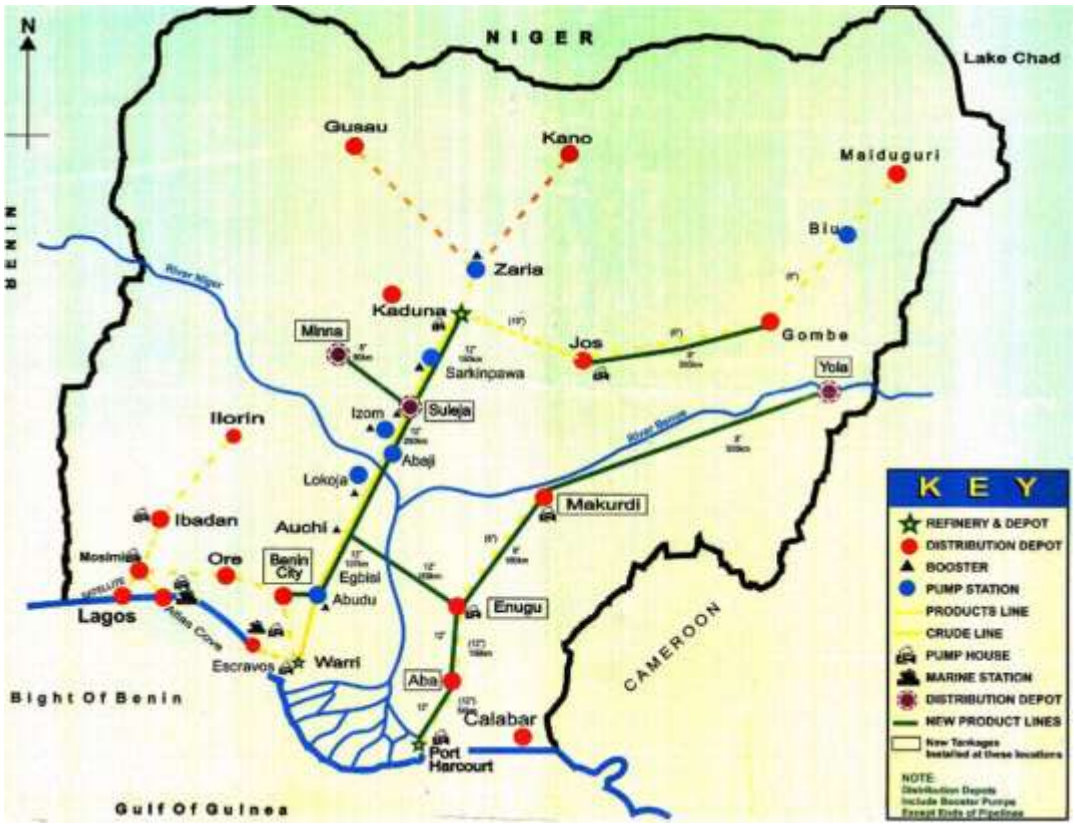

Figure 4.2. ***Catchment Areas of Respective Depots***

Source: ***Nigeria Extractive Industries Transparency Initiative***

From the map in figure 4.2, we can see that the table below (4.1) shows the states that are dependent on each of the depots across the country.

Table 4.1: ***Depots and their respective Catchment States.***

DEPOTS	STATES		DEPOTS	STATES
ABA	Abia Imo		ATLAS COVE	Lagos
BENIN	Edo		SATELLITE	Lagos
CALABAR	Cross river Akwa Ibom		MOSIMI	Ogun Osun
ENUGU	ENUGU Ebonyi Anambra		MAKURDI	Benue
GUSAU	Zamfara Sokoto Kebbi		MAIDUGURI	Borno Yobe
GOMBE	GOMBE		MINNA	Niger
IBADAN	Oyo		ORE	Ondo Ekiti
ILORIN	Kwara		PORT HARCOURT	Rivers
JOS	Plateau Bauchi		SULEJA	Kogi Abuja Nasarawa
KADUNA	Kaduna		WARRI	Bayelsa Delta
KANO	Kano Katsina Jigawa		YOLA	Adamawa Taraba

From the table above (table 4.1) the demand of major products by the various depots across the country can thus be given in the table 4.2, 4.3 and 4.4 for PMS, AGO and HHK, respectively for the period under consideration.

Table 4.2: ***DEMAND FOR PMS PRODUCT BY DEPOTS SINCE 2007 (SOURCE NNPC PMI FIGURES)***

PREMIUM MOTOR SPIRIT DEMAND DEPOT							,000 Litres		
DEPOTS	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
ABA	146629.09	160664.17	165649.08	194974.85	203946.86	295890.69	222087.91	212238.32	212344.10
BENIN	180015.17	151659.77	167589.35	179844.60	192008.76	236129.36	179374.10	250774.08	250065.71
CALABAR	174191.00	182126.39	204498.93	227629.12	220087.53	349175.86	210265.96	275088.44	274453.98
ENUGU	127923.97	257138.10	210339.67	305666.17	251773.36	360613.95	278007.30	264602.36	264744.56
GUSAU	118556.06	228817.84	253350.54	342066.99	478239.95	466330.31	407549.59	298931.87	300023.93
GOMBE	42701.58	87430.76	67185.32	95045.42	149661.33	178694.48	104464.99	67743.18	68117.79
IBADAN	468365.13	384528.64	346382.48	485617.43	285938.96	167476.14	416437.01	380976.46	381306.29
ILORIN	160758.48	105144.23	104710.03	129061.01	134052.01	114679.82	160679.85	126741.80	127076.60
JOS	182271.67	222016.18	210161.58	385141.10	416111.84	444489.12	347261.89	279111.63	279802.82
KADUNA	221201.69	269799.83	294327.58	409852.10	524570.54	577075.87	284013.92	213877.45	214608.07
KANO	398204.82	490325.01	557026.02	769428.89	843047.76	689472.94	625212.09	445169.97	446976.97
ATLAS COVE	2147697.92	1404797.32	1297711.46	1467279.85	772218.61	395782.06	1083031.43	1053527.71	1053754.41
SATELLITE	292867.90	191563.27	176960.65	200083.62	105302.54	53970.28	147686.10	143662.87	143693.78
MOSIMI	630728.17	397549.83	421426.24	628512.58	327016.85	350454.10	677820.87	486978.66	488854.33
MAKURDI	75041.36	87300.83	87342.04	107767.68	128152.20	160131.58	83263.38	69148.83	69297.63
MAIDUGURI	151512.02	201923.11	210404.95	257487.18	330343.69	266013.59	313900.05	221046.61	221970.42
MINNA	270321.90	492736.46	277652.34	339086.64	216895.96	194236.31	184257.34	144763.85	145159.81
ORE	228997.60	184817.50	164938.58	290218.70	280231.08	313635.25	291580.20	251955.30	252353.72
PORT HARCOURT	435227.52	488342.96	379805.28	448485.07	378424.17	470161.07	379154.50	366210.25	366348.71
SULEJA	914441.97	764180.74	880866.28	1312597.40	1236376.12	1519705.82	884982.48	804030.38	804903.09
WARRI	234641.43	310908.33	247643.09	298675.99	319738.37	500813.39	288216.97	334903.80	334458.01
YOLA	123465.57	142957.73	150605.50	215947.63	248215.50	286100.01	252879.08	221960.16	222272.63

Table 4.3: ***DEMAND FOR AGO PRODUCT BY DEPOTS SINCE 2007 (SOURCE NNPC PMI FIGURES)***

AUTOMATED GAS OIL DEMAND **DEPOT**

DEPOTS	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABA	72685.12	39577.77	33163.23	63908.80	92090.08	81412.16	70209.71	91634.52	82253.27
BENIN	43148.37	48399.08	49274.84	79363.31	134282.72	80245.14	62455.22	81513.71	73168.60
CALABAR	49312.53	30223.71	21391.35	45921.68	77283.80	64299.65	63819.23	83293.95	74766.58
ENUGU	57629.38	127592.86	111136.46	68501.02	108881.46	219433.69	201894.44	263503.43	236526.80
GUSAU	30832.84	31310.07	21793.83	68665.07	88642.96	75574.58	71335.89	93104.35	83572.63
GOMBE	10403.33	13393.19	11281.77	58472.37	49410.50	34154.52	27358.31	35706.82	32051.27
IBADAN	62304.65	32062.64	36103.85	71451.54	67507.80	49886.08	36595.19	47762.37	42872.61
ILORIN	47217.07	5764.23	8981.63	32162.49	43367.02	20828.62	9404.84	12274.77	11018.11
JOS	82836.22	40384.19	30186.87	81318.00	105069.64	89370.33	69611.66	90853.97	81552.63
KADUNA	51409.32	106580.21	55010.70	184593.76	169480.64	80746.84	57014.98	74413.36	66795.16
KANO	58317.33	83047.02	95663.33	168717.60	200580.01	156213.29	133898.98	174758.86	156867.61
ATLAS COVE	229969.47	154355.74	155883.38	289085.38	206005.59	180522.47	149542.57	195176.15	175194.64
SATELLITE	31359.47	21048.51	21256.82	39420.73	28091.67	24616.70	20392.17	26614.93	23890.18
MOSIMI	30323.53	37970.81	57378.95	64689.17	92767.56	71195.69	58526.24	76385.78	68565.65
MAKURDI	6556.75	71197.52	7347.09	20220.96	36908.80	21516.71	29894.15	39016.48	35022.10
MAIDUGURI	19881.87	13606.60	18854.16	58067.62	78472.53	38795.61	34405.87	44904.97	40307.74
MINNA	16440.86	8927.08	10350.56	34247.32	43821.23	35409.80	21156.62	27612.65	24785.76
ORE	15212.20	299510.50	8707.58	24747.62	61977.88	39585.25	18825.83	24570.61	22055.15
PORT HARCOURT	223877.85	213608.83	207699.33	353314.09	159634.86	257498.23	239632.02	312756.81	280737.77
SULEJA	58778.38	54542.03	66137.10	160072.53	199807.37	138615.48	139490.68	182056.89	163418.49
WARRI	103379.71	74530.56	101802.87	144224.76	162609.42	156090.72	131115.47	171125.94	153606.61
YOLA	21341.98	25522.17	19065.63	50570.34	53567.05	41233.36	70872.57	92499.65	83029.84

Table 4.4: ***DEMAND FOR HHK PRODUCT BY DEPOTS SINCE 2007 (SOURCE NNPC PMI FIGURES)***

HOUSE HOLD KEROSENE DEMAND DEPOT

DEPOTS	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABA	114749.37	59725.28	38926.52	68863.62	85407.35	108996.75	108715.39	128724.41	128524.32
BENIN	37448.79	116559.65	79057.00	189785.44	174986.09	86153.37	84649.15	107411.80	107184.41
CALABAR	78483.52	29187.74	21766.63	92834.34	104200.17	127503.11	99227.44	137577.75	137197.05
ENUGU	56872.97	48780.05	51013.65	104771.57	130392.22	135547.08	131195.53	135411.24	135369.52
GUSAU	167974.33	51475.63	26859.50	95753.01	110695.66	166432.25	192328.34	136557.13	137112.19
GOMBE	18806.90	11932.15	14303.24	40852.78	66981.49	68007.48	49298.49	33541.98	33701.418
IBADAN	37371.79	39608.10	38461.56	49647.07	58367.49	73105.06	196522.44	163862.04	164176.29
ILORIN	2388.86	15253.87	25389.50	32649.36	50214.44	45310.73	75827.07	57133.95	57317.829
JOS	49758.08	45011.55	38314.09	91237.02	124124.30	164955.51	163877.74	125041.30	125429.73
KADUNA	37109.70	160182.00	55980.04	261690.26	218980.84	216310.83	134030.14	113942.81	114151.91
KANO	103193.93	64959.60	121427.30	193694.89	167277.91	246423.38	295046.32	198385.04	199346.71
ATLAS COVE	260341.39	192385.34	386686.52	335035.56	237502.54	168772.61	511097.66	420730.27	421599.78
SATELLITE	35501.10	26234.37	52729.98	45686.67	32386.71	23014.45	69695.14	57372.31	57490.88
MOSIMI	100189.08	82054.48	116318.57	101207.98	153971.26	137026.89	319873.14	213082.41	214132.05
MAKURDI	10774.04	308171.30	9345.76	35036.40	53277.67	53207.96	39293.15	34844.47	34890.345
MAIDUGURI	8193.53	17649.50	95485.26	75567.83	91157.92	95282.00	148133.82	113285.05	113628.25
MINNA	25301.97	17661.14	23633.86	56249.72	54208.45	90613.35	86953.61	64527.65	64752.235
ORE	43774.72	34274.55	51320.62	65781.33	96800.70	119026.12	137600.77	108754.07	109040.66
PORT HARCOURT	454508.10	245283.02	143723.05	237239.22	221773.70	169602.85	178928.31	188191.52	188098.01
SULEJA	60606.63	56924.85	143460.92	301778.55	257267.88	522918.80	417635.59	330207.80	331092.34
WARRI	20725.61	309213.84	343459.95	453045.12	285380.98	197361.07	136013.61	173000.34	172636.7
YOLA	35046.59	17309.00	21058.49	68059.27	93940.24	107707.34	119337.17	104327.77	104476.69

Table 4.5: ***SUPPLY OF PMS PRODUCT TO DEPOTS SINCE 2007 (SOURCE NNPC PMI FIGURES)***

PREMIUM MOTOR SPIRIT SUPPLY DEPOT	**,000 Litres**

DEPOTS	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABA	154264.47	165073.75	237925.83	225538.63	242091.18	348131.44	451280.06	418260.21	613549.56
BENIN	189389.05	155822.23	240712.69	208036.61	227920.29	277819.00	364486.10	494203.03	287620.93
CALABAR	183261.61	187125.03	293726.82	263311.71	261250.66	410824.32	427257.99	542119.58	701702.75
ENUGU	134585.33	264195.51	302116.02	353581.65	298862.71	424281.86	564907.61	521454.56	885981.72
GUSAU	124729.60	235097.97	363893.58	395688.58	567685.50	548662.89	828136.04	589108.07	886031.60
GOMBE	44925.17	89830.38	96499.92	109944.51	177652.59	210243.74	212271.64	133502.18	334440.75
IBADAN	492754.20	395082.41	497517.64	561741.64	339418.32	197044.76	846195.18	750794.18	827356.20
ILORIN	169129.62	108030.02	150397.58	149292.30	159123.85	134927.02	326499.59	249771.36	410115.38
JOS	191763.06	228109.64	301860.23	445514.88	493937.52	522965.55	705632.13	550048.12	707136.14
KADUNA	232720.28	277204.75	422749.91	474099.52	622681.33	678961.05	577112.99	421490.46	1146027.04
KANO	418940.44	503782.46	800070.11	890042.69	1000723.57	811202.29	1270423.71	877300.98	1278359.14
ATLAS COVE	2259534.50	1443353.37	1863934.74	1697287.07	916647.19	465659.04	2200707.30	2076197.76	3307596.86
SATELLITE	308118.34	196820.91	254172.92	231448.24	124997.34	63498.96	300096.45	283117.88	451035.94
MOSIMI	663571.94	408460.98	605304.82	727036.68	388179.04	412328.24	1377324.14	959693.79	632958.28
MAKURDI	78948.97	89696.89	125451.50	124661.08	152120.60	188403.48	169190.23	136272.30	171494.00
MAIDUGURI	159401.67	207465.09	302209.78	297850.24	392128.10	312979.41	637841.26	435618.80	659167.61
MINNA	284398.31	506260.10	398798.86	392241.04	257462.16	228529.55	374408.77	285287.59	351539.29
ORE	240922.14	189890.00	236905.31	335712.68	332642.89	369008.87	592487.59	496530.88	761802.34
PORT HARCOURT	457891.03	501746.02	545523.62	518788.50	449201.10	553169.99	770437.55	721694.27	1043108.32
SULEJA	962059.49	785154.44	1265209.81	1518356.98	1467616.40	1788016.27	1798274.13	1584510.84	2877925.24
WARRI	246859.86	319441.52	355695.84	345495.71	379539.26	589234.11	585653.54	659998.33	1005312.60
YOLA	129894.76	146881.34	216318.37	249799.06	294639.41	336612.17	513847.36	437419.13	617401.34

Table 4.6: ***SUPPLY OF AGO PRODUCT BY DEPOTS SINCE 2007 (SOURCE NNPC PMI FIGURES)***

AUTOMATED GAS OIL SUPPLY **DEPOT**									
DEPOTS	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABA	38735.72	30387.32	18253.39	38230.77	71669.81	40177.89	44190.59	188994.87	187546.46
BENIN	22063.85	38005.68	28667.87	47241.46	106539.70	43266.94	45717.01	109459.83	108822.22
CALABAR	19654.07	23461.04	9719.15	27023.58	60093.80	29945.36	34850.24	126903.68	125982.69
ENUGU	25965.52	94257.05	44088.94	43873.04	86228.90	138453.65	152333.97	273069.78	271860.98
GUSAU	13342.03	24143.68	11976.35	43849.63	68393.84	32528.33	37846.84	170879.49	169548.67
GOMBE	4041.96	10955.64	6457.80	33679.93	38858.86	12057.52	12988.36	63428.80	62924.33
IBADAN	29588.54	26013.39	21661.24	44214.91	53092.40	24988.66	25903.36	87577.75	86960.94
ILORIN	15552.50	4930.47	5286.79	18772.26	33622.92	5153.57	4222.63	43675.17	43280.76
JOS	31521.99	33793.27	18328.13	52563.59	82162.97	31163.68	33395.04	173471.46	172070.53
KADUNA	21701.66	94218.37	33922.59	114688.19	139256.42	40471.76	41233.42	137815.29	136849.49
KANO	27899.11	63889.14	54661.40	103405.53	149422.21	81454.83	89401.22	199951.42	198845.19

ATLAS COVE	123450.48	122578.48	88824.53	186084.43	148353.85	121788.93	129861.27	83084.39	83551.38
SATELLITE	16834.16	16715.25	12112.44	25375.15	20230.07	16607.58	17708.36	11329.69	11393.37
MOSIMI	14095.41	30988.91	32471.81	40760.59	71138.87	30411.16	33122.54	145393.75	144270.81
MAKURDI	2940.43	66404.08	4159.95	12628.72	28453.38	8485.94	11816.23	68282.03	67717.06
MAIDUGURI	8646.38	11035.89	10581.31	35363.98	57943.48	12749.55	14962.10	134143.39	132951.41
MINNA	6846.56	7225.61	6087.04	21392.62	31724.43	11034.76	9579.72	77112.01	76436.85
ORE	6190.88	283765.81	4807.60	15933.42	47930.10	10888.70	9426.06	98437.57	97547.64
PORT HARCOURT	111206.99	168920.61	118064.18	208185.82	127138.61	172406.89	189441.40	235956.96	235490.05
SULEJA	29509.77	43758.77	38622.62	101217.81	152992.66	51763.90	62241.10	305540.89	303106.94
WARRI	46461.35	55806.27	68466.98	89832.83	134798.37	81950.67	88719.18	333565.51	331116.42
YOLA	10033.68	21948.40	11194.76	32042.91	40419.00	15472.51	24344.38	151089.97	149821.65

Table 4.7: ***SUPPLY OF HHK PRODUCT TO DEPOTS SINCE 2007 . (SOURCE NNPC PMI FIGURES)***

HOUSE HOLD KEROSENE SUPPLY DEPOT									
DEPOTS	2007	2008	2009	2010	2011	2012	2013	2014	2015
ABA	180931.40	90802.72	59726.82	92180.24	115607.22	144403.66	133612.54	166248.57	251967.87
BENIN	59047.49	177210.27	121300.93	254045.13	236860.83	114139.76	107915.06	131406.44	137520.02
CALABAR	123749.12	44375.28	33397.58	124267.24	141045.15	168921.70	126500.22	194475.61	236620.35
ENUGU	89674.61	74162.25	78272.67	140246.31	176498.66	179578.71	167254.77	206744.77	326727.52
GUSAU	264854.00	78260.44	41211.81	128174.14	149837.43	220496.73	245190.01	253852.74	270978.51
GOMBE	29653.83	18140.92	21946.14	54685.18	90666.02	90099.28	62848.23	103729.20	127874.75
IBADAN	58926.07	60217.77	59013.41	66457.14	79006.12	96852.78	250536.86	111504.34	122903.72
ILORIN	3766.64	23191.07	38956.33	43704.14	67970.17	60029.64	96668.22	69110.72	75574.69
JOS	78456.20	68432.85	58787.15	122129.08	168014.41	218540.27	208919.72	251600.32	288083.62
KADUNA	58512.82	243531.07	85892.85	350296.31	296412.04	286578.05	170868.47	329930.63	215227.36
KANO	162711.32	98760.66	186311.71	259278.29	226427.05	326472.48	376140.13	375860.15	298698.32

ATLAS COVE	410494.01	292491.09	593311.59	448475.69	321482.98	223597.34	651573.43	257422.39	41945.45
SATELLITE	55976.46	39885.15	80906.13	61155.78	43838.59	30490.55	88850.92	35103.05	5719.83
MOSIMI	157973.42	124750.70	178473.13	135476.12	208415.20	181539.22	407790.63	209001.87	248794.85
MAKURDI	16988.00	468525.09	14339.65	46899.41	72116.55	70492.24	50092.92	81156.07	125398.57
MAIDUGURI	12919.18	26833.24	146507.60	101154.44	123391.18	126233.76	188848.57	145329.98	230240.74
MINNA	39894.95	26850.93	36262.55	75295.39	73376.45	120048.52	110852.91	138209.06	121060.27
ORE	69021.91	52108.97	78743.67	88054.32	131029.24	157691.02	175420.50	181545.99	158957.73
PORT HARCOURT	716646.93	372913.54	220521.14	317566.36	300192.46	224697.27	228106.95	258688.73	278796.35
SULEJA	95561.68	86545.11	220118.95	403958.15	348237.30	692785.70	532423.21	797588.00	541054.57
WARRI	32679.16	470110.10	526987.00	606442.25	386291.15	261472.58	173397.11	301027.28	463920.53
YOLA	55259.80	26315.56	32311.04	91103.55	127157.32	142695.40	152137.13	164281.88	278551.59

4.3 Forecast Results

The model of the forecasting reported in the methodology was estimated using the data analysis tool pack in the Microsoft excel package of Microsoft office suite. Table 4.8 and 4.9 shows the forecast of the demand by states and by depots for PMS, AGO and HHK, in 2016.

Table 4.8 Forecast Results by states

DEMAND in 2016								**,000 Litres**
STATE	**PMS**	**AGO**	**HHK**		**STATE**	**PMS**	**AGO**	**HHK**
Abia	96525.15	38458.91	69580.34		Katsina	123938.14	11503.52	58022.82
Adamawa	162138.53	57867.99	72926.36		Kebbi	123831.33	29123.74	56867.24
Akwa-Ibom	162026.45	40000.82	82321.40		Kogi	75922.58	22290.22	37511.79
Anambra	184155.07	15366.62	83116.32		Kwara	127338.37	11128.62	57456.16
Bauchi	149221.65	36699.85	66220.74		Lagos	1197027.24	200875.78	479638.71
Bayelsa	56250.02	20524.48	39550.70		Nasarawa	57022.85	23657.14	32234.84

Benue	69497.34	35323.30	34943.98		Niger	145528.57	25018.86	64954.04
Borno	158343.34	25935.78	77344.02		Ogun	372003.53	53369.67	158543.37
Cross-Rivers	111968.81	35425.20	54555.97		Ondo	120398.59	15080.29	52045.73
Delta	277979.94	134459.36	132824.21		Osun	118244.75	15813.94	56369.96
Ebonyi	33334.21	162845.35	22965.63		Oyo	381392.66	43264.97	164346.48
Edo	249474.76	73835.14	106989.95		Plateau	131287.46	45591.53	59555.13
Ekiti	132330.23	7191.60	57233.61		Rivers	366546.78	283218.30	188010.69
Enugu	47447.29	60402.52	29253.12		Sokoto	107900.73	36992.26	49172.38
Gombe	68518.31	32341.71	33861.36		Taraba	60441.09	25864.09	31672.22
Imo	115971.36	44530.20	58761.63		Yobe	64421.01	14734.81	36544.99
Jigawa	54661.50	22826.33	27443.52		Zamfara	69327.36	18197.41	31543.10
Kaduna	215522.92	67415.63	114414.65		Abuja	673286.62	118914.06	262210.53
Kano	270075.71	123944.65	114694.46					

Demand Forecast Results By States.

Table 4.9: ***Demand Forecast Results By Depots***

Demand by depots 2016			**,000 Litres**
Depot	**PMS**	**AGO**	**HHK**
ABA	212497	82989	128342
BENIN	249475	73835	106990
CALABAR	273995	75426	136877
ENUGU	264937	238614	135335
GUSAU	301059	84313	137583
GOMBE	68518	32342	33861
IBADAN	381393	43265	164346
ILORIN	127338	11129	57456
JOS	280509	82291	125776
KADUNA	215523	67416	114415

KANO	448675	158274	200161
ATLAS COVE	1053384	176771	422082
SATELLITE	143643	24105	57557
MOSIMI	490248	69184	214913
MAKURDI	69497	35323	34944
MAIDUGURI	222764	40671	113889
MINNA	145529	25019	64954
ORE	252729	22272	109279
PORT HARCOURT	366547	283218	188011
SULEJA	806232	164861	331957
WARRI	334230	154984	172375
YOLA	222580	83732	104599

Table 4.10: ***Supply Forecast Results By States.***

SUPPLY in 2016								**,000 Litres**
STATE	**PMS**	**AGO**	**HHK**		**STATE**	**PMS**	**AGO**	**HHK**
Abia	253271.59	92341.02	104717.20		Katsina	382770.38	42427.23	80052.96
Adamawa	420165.07	95159.34	174584.27		Kebbi	355163.44	68423.35	126112.14
Akwa-Ibom	429221.80	64291.86	133224.19		Kogi	317507.76	62882.00	114455.24
Anambra	452230.89	55707.14	85352.34		Kwara	394659.01	42929.29	75167.78
Bauchi	330093.69	84631.95	146890.67		Lagos	3618204.59	95417.40	76156.66
Bayelsa	168402.47	88071.53	157970.44		Nasarawa	546793.32	68334.25	113260.58
Benue	168316.32	67207.40	120684.00		Niger	345663.71	75832.45	122506.10

Borno	444232.08	76525.23	129455.47		Ogun	346821.12	88229.57	137119.18
Cross-Rivers	255342.66	60860.15	98541.31		Ondo	346040.53	45520.13	76749.50
Delta	801617.53	240839.38	288487.13		Osun	322022.85	55031.87	109460.00
Ebonyi	72965.85	116616.44	85639.21		Oyo	820021.25	86407.67	122998.50
Edo	306890.14	108251.82	136692.28		Plateau	362703.29	86180.45	137121.86
Ekiti	389967.04	51231.25	84384.96		Rivers	1011227.40	235050.75	276484.01
Enugu	324614.12	98431.40	143354.39		Sokoto	305762.82	48537.41	67195.11
Gombe	315128.61	62472.05	125078.30		Taraba	179820.41	53515.21	92407.49
Imo	340965.32	93901.03	138360.03		Yobe	194284.98	55355.62	92666.29
Jigawa	144657.96	49885.04	90710.82		Zamfara	197523.93	51388.66	75840.00
Kaduna	1075224.28	135989.05	225224.05		Abuja	1886378.26	169700.16	336466.71
Kano	714314.72	105536.38	135594.10					

Table 4.11: ***Supply Forecast Result By Depots***

Supply by depots 2016			**,000 Litres**
Depot	**PMS**	**AGO**	**HHK**
ABA	594237	186242	243077
BENIN	306890	108252	136692
CALABAR	684564	125152	231765
ENUGU	849811	270755	314346
GUSAU	858450	168349	269147
GOMBE	315129	62472	125078
IBADAN	820021	86408	122999
ILORIN	394659	42929	75168

JOS	692797	170812	284013
KADUNA	1075224	135989	225224
KANO	1241743	197849	306358
ATLAS COVE	3184020	83967	67018
SATELLITE	434185	11450	9139
MOSIMI	668844	143261	246579
MAKURDI	168316	67207	120684
MAIDUGURI	638517	131881	222122
MINNA	345664	75832	122506
ORE	736008	96751	161134
PORT HARCOURT	1011227	235051	276484
SULEJA	2750679	300916	564183
WARRI	970020	328911	446458
YOLA	599985	148675	266992

4.4 Linear Programming Model

This dissertation uses solver of Microsoft Excel integrated with Pyomo scripts to minimize the transportation costs. While considering the mode of transport to be solely by pipeline. The year 2016 oil demand by depot is shown in table 4.9. Three refineries and the cost of transporting these products to the various 22 depots across the country. All costs are measured in Naira (₦).

My choice of software package for solving the linear programming problem is Pyomo integrated in Microsoft excel suite, this is because of its ability to understand program written with regards to solving different linear programming models. Also Pyomo and pulp are well known scripts which can efficiently solve transportation problem without glitches.

The objective function of this linear programming model is to minimize the overall cost of transporting PMS, AGO and HHK from the three refineries to the various 22 depots across the country. Based on the assumption made on this dissertation, we bear in mind that the depots cannot get more than the capacity it can contain.

Based on the data with regards to the cost in metric ton, we convert the amount in litres of various products to metric ton with reference to their respective densities. The table below gives the conversion from litres to metric ton and their respective densities.

Table 4.12: ***Conversion Rates From Litres To Metric Tonnes***

Product	Density (kg/m^3)	Litres /Metric ton *(nearest whole number)*
PMS	737.22	1356
AGO	885	1130
HHK	817.15	1224

The data given is the cost of transportation in metric ton from refineries to depots as presented in table 4.11

Table 4.13: Cost of transporting products from Refineries to Depots in ₦ *per Metric tonne*

REFINERIES / DEPOTS	PHRC	KRPC	WRPC
ABA	54	725	522
BENIN	486	507	90
CALABAR	256	1130	805
ENUGU	210	569	366
GUSAU	1039	260	857
GOMBE	1209	430	1027
IBADAN	830	851	434
ILORIN	1000	1021	604
JOS	944	165	762
KADUNA	990	30	630
KANO	1002	223	820
ATLAS COVE	880	1102	603
SATELLITE	883	1152	632
MOSIMI	751	772	355
MAKURDI	390	749	546
MAIDUGURI	1506	727	1324
MINNA	709	230	527
ORE	600	621	204
PORT HARCOURT	25	973	439
SULEJA	629	150	447
WARRI	688	857	15
YOLA	895	1254	1051

Source: Planning and Budget Monitoring Department of the NNPC.

Therefore our demand forecast table in metric ton

Table 4.14 : Demand forecast in 2016 by Depots in Metric tonnes

DEPOT	PMS	AGO	HHK

ABA	156708	73442	104855
BENIN	183978	65341	87410
CALABAR	202061	66749	111828
ENUGU	195381	211163	110568
GUSAU	222020	74614	112404
GOMBE	50530	28621	27665
IBADAN	281263	38288	134270
ILORIN	93907	9848	46941
JOS	206865	72824	102758
KADUNA	158940	59660	93476
KANO	330882	140066	163530
ATLAS COVE	776832	156434	344838
SATELLITE	105932	21332	47023
MOSIMI	361540	61224	175583
MAKURDI	51252	31260	28549
MAIDUGURI	164280	35992	93047
MINNA	107322	22141	53067
ORE	186378	19710	89281
PORT HARCOURT	270315	250636	153604
SULEJA	594566	145895	271207
WARRI	246482	137154	140829
YOLA	164144	74099	85456

4.5 Supply Forecast

Based on the assumption that the refineries are working in full capacity, it cannot be over emphasized that the production from the three refineries can actually produce at full capacity all the time but however it is assumed that the refineries can cater for the demand of the country

regardless of the importation of finished products, the supply forecast from the refineries to depots in line with the products demand in 2016 is hence given by the table below.

Table 4.15: Supply by Refineries 2016 to Depots *per metric ton*

Depot	PMS	AGO	HHK
ABA	438228	164816	215113
BENIN	226320	95798	120967
CALABAR	504841	110754	205102
ENUGU	626704	239606	278182
GUSAU	633075	148982	238183
GOMBE	232396	55285	110689
IBADAN	604735	76467	108848
ILORIN	291046	37991	66520
JOS	510912	151161	251339
KADUNA	792938	120344	199313
KANO	915740	175087	271113
ATLAS COVE	2348097	74307	59308
SATELLITE	320195	10133	8087
MOSIMI	493248	126780	218212
MAKURDI	124127	59476	106800
MAIDUGURI	470883	116709	196568
MINNA	254914	67108	108412
ORE	542778	85621	142597
PORT HARCOURT	745743	208010	244676
SULEJA	2028525	266298	499277
WARRI	715354	291072	395095
YOLA	442467	131570	236276

The above table 4.13 shows the amount of products supplied by the refineries to the depot, therefore the total amount of products to be supplied by the refineries is hence given by

Table 4.16: Forecast of supply by refineries *in Metric Tonnes*

PMS	AGO	HHK
14263268	2813374	4280677

Splitting these supplies by the percentage of the installed production capacity of the refineries, we have the below table

Table 4.17 : Installed refining capacity of Nigerian refineries

PHRC	KRPC	WRPC
47%	25%	28%

Source calculations based on Original installed capacities Vanguard.

From the installed capacities, we distribute the production based on the capacity percentage of each refinery. Therefore, we have the table below,

Table 4.18: ***Supply Forecast By Refineries For 2016***

	PHRC	KRPC	WRPC
PMS	6703736	3565817	3993715
AGO	1322286	703344	787745
HHK	2011918	1070169	1198590

Having analyzed the data provided we move on to the main problem of optimization. The forecast of 2016 would be optimized using the *Pyomo* script in appendix II embedded in Microsoft excel solver, this script does the work of minimizing the cost of transportation from refineries to the 22 depots in the country. Since the cost of transporting these products is proportional to the distances, It also recommends a better supply channel from refineries to the depots.

The model for the transportation problem is translated in Appendix I using the actual variables is given below for the three different products. Using the model above this problem is hence optimized in the screen shots below

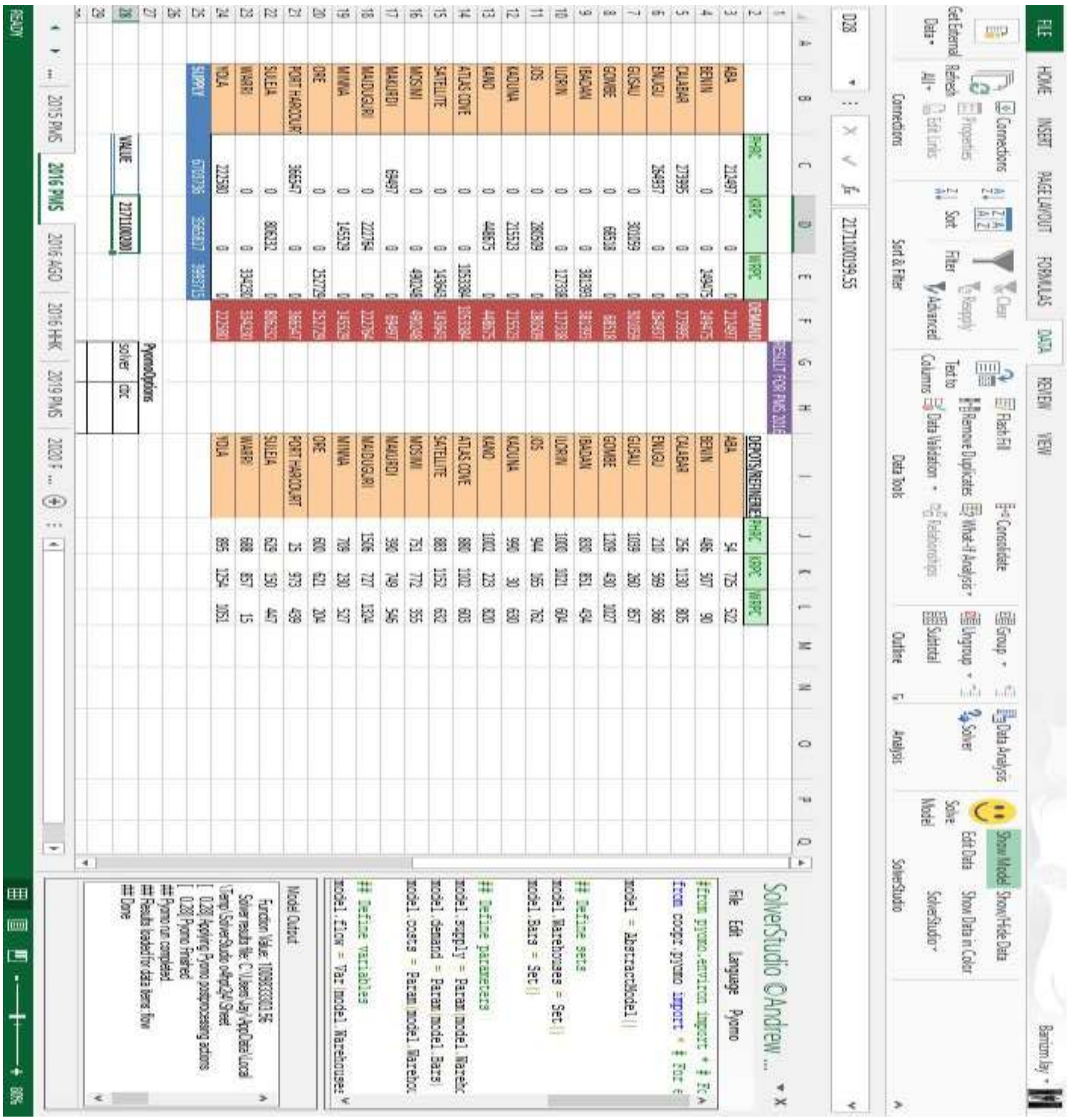

FIGURE 4.3: ***Excel PMS optimization***

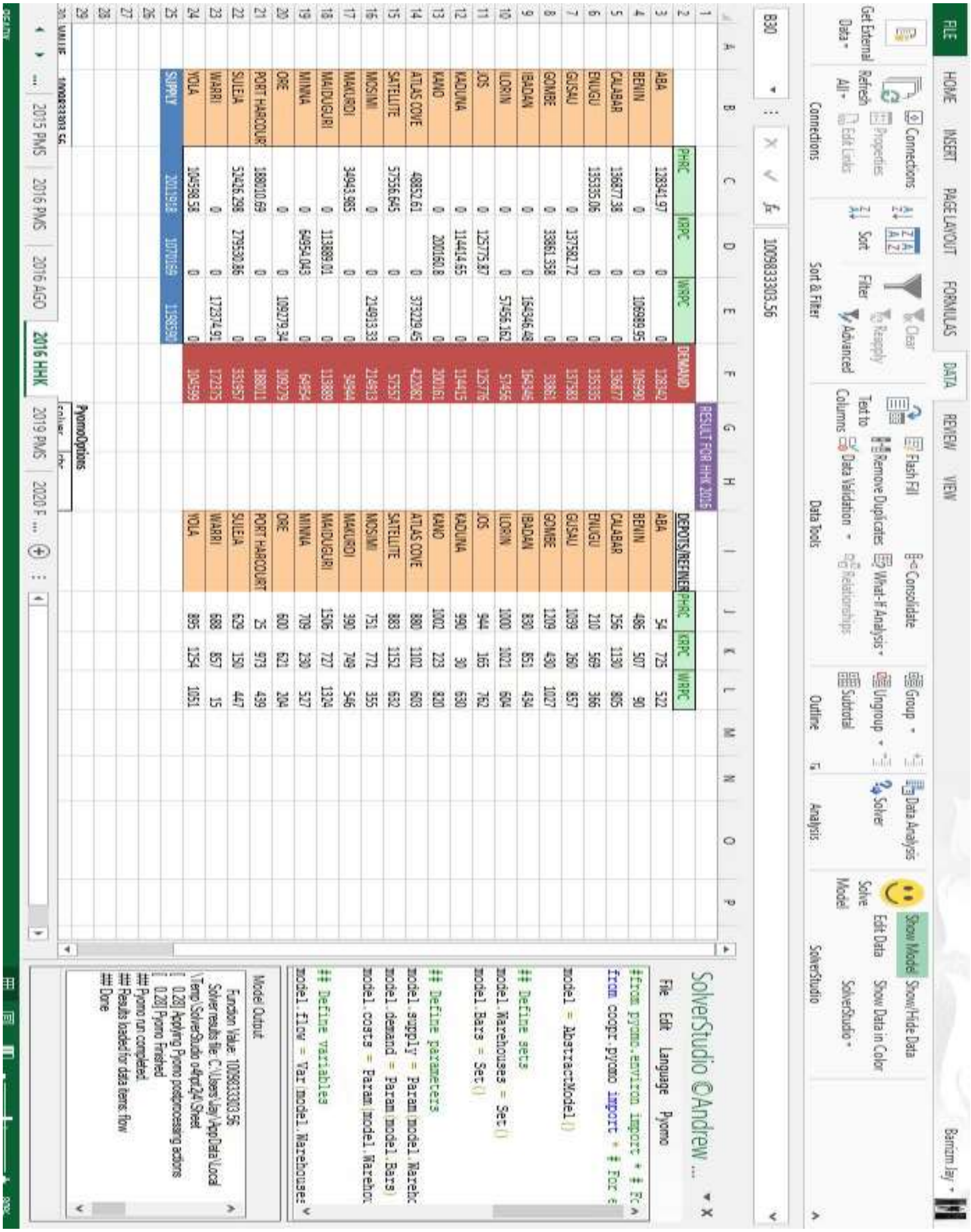

FIGURE 4.4: ***Excel HHK optimization***

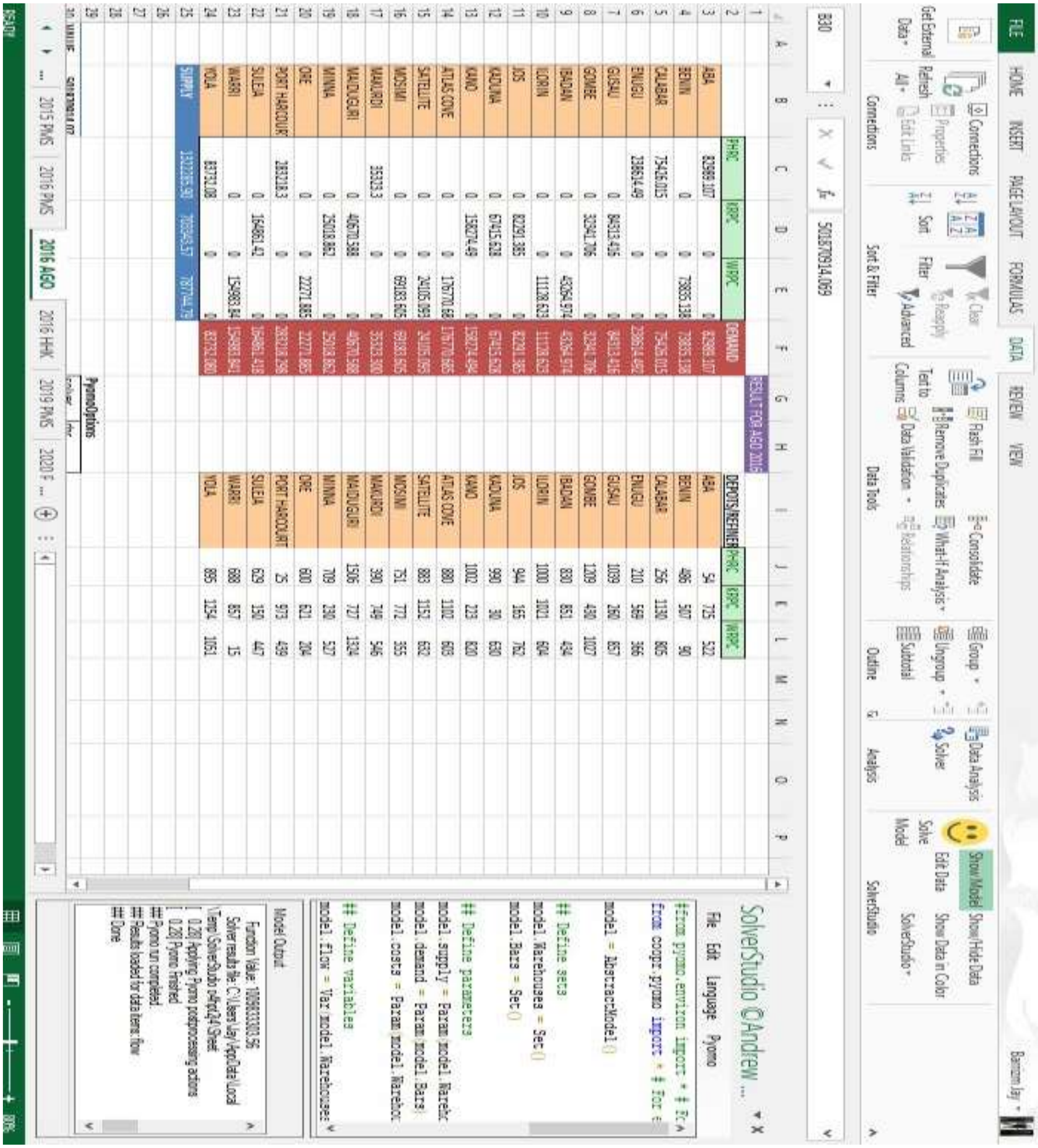

FIGURE 4.5: ***Excel AGO optimization***

4.6 Discussion and Results

The objective of this study is to make a one year forecast of the demand and supply of major petroleum products in the country and then develop a linear programming model that will minimize the cost of transporting these products from the refineries to various depots across the nation through pipeline. The results of the objective are below.

The result of the study considered two important factors in the schedule of the distribution. The factors are

1. The pipeline distance of storage depots from refineries.
2. The product availability in refineries.

In the Premium Motor Spirit (PMS) the forecast result for both demand and supply in metric tonnes shown in table 4.14 and 4.18 respectively was used to obtain the best schedule, the best schedule was obtained and the results presented in the table below,

Table 4.19: Optimal Schedule for PMS Supply In Metric Tonnes

PHRC		**KRPC**		**WRPC**	
Depots	Supply	Depots	Supply	Depots	Supply
ABA	212497	GUSAU	301059	BENIN	249475
CALABAR	273995	GOMBE	68518	IBADAN	381393
ENUGU	264937	JOS	280509	ILORIN	127338
MAKURDI	69497	KADUNA	215523	ATLAS COVE	1053384
PORT HARCOURT	366547	KANO	448675	SATELLITE	143643
YOLA	222580	MAIDUGURI	222764	MOSIMI	490248
		MINNA	145529	ORE	252729
		SULEJA	806232	WARRI	334230
TOTAL	**1410053**		**2488809**		**3032440**
OPTIMAL COST = ₦ 2,171,100,200					

Table 4.19 shows the optimal schedule and the supply figures in metric tonnes from refineries to depots, having this optimal schedule, the optimal cost for this schedule is given as: Two Billion, One Hundred And Seventy One Million, One Hundred Thousand, Two Hundred Naira.

For AGO the optimal schedule is given in the table below:

Table 4.20: Optimal Schedule for AGO For 2016 Supply in Metric Tonnes

PHRC		KRPC		WRPC	
Depots	Supply	Depots	Supply	Depots	Supply
ABA	82989	GUSAU	84313	BENIN	73835
CALABAR	75426	GOMBE	32342	IBADAN	43265
ENUGU	238614	JOS	82291	ILORIN	11129
MAKURDI	283218	KADUNA	67416	ATLAS COVE	176771
PORT HARCOURT	283218	KANO	158274	SATELLITE	24105
YOLA	83732	MAIDUGURI	40671	MOSIMI	69184
		MINNA	25019	ORE	22272
		SULEJA	164861	WARRI	154984
TOTAL	**1047197**		**655187**		**575545**
OPTIMAL COST = ₦ 501,870,914					

Table 4.20 shows the supply of AGO from the refineries to depots and the optimal cost of AGO schedule is therefore given by: Five Hundred And One Million, Eight Hundred And Seventy Thousand, Nine Hundred and Fourteen Naira.

Table 4.21: Optimal Schedule for HHK Supply In Metric Tonnes

PHRC		KRPC		WRPC	
Depots	Supply	Depots	Supply	Depots	Supply
ABA	128342	GUSAU	137583	BENIN	106990
CALABAR	136877	GOMBE	33861	IBADAN	164346
ENUGU	135335	JOS	125776	ILORIN	57456
ATLAS COVE **	48853	KADUNA	114415	ATLAS COVE **	373229
SATELLITE	57557	KANO	200161	MOSIMI	214913
MAKURDI	34944	MAIDUGURI	113889	ORE	109279
PORT HARCOURT	188011	MINNA	64954	WARRI	172375
SULEJA**	52426	SULEJA**	279531	BENIN	106990
YOLA	104599				
TOTAL	**886944**		**1070170**		**1305578**
OPTIMAL COST = ₦ 1,009,833,304					

For HHK we notice in table 4.21 above that Atlas Cove depot cannot be satisfied by PHRC alone therefore would resort to WRPC to supply the rest of the needed product demanded. Same applies to Suleja depot as its required demand cannot be supplied by PHRC alone so would also resort to KRPC to supply the rest of the demanded product. Therefore the optimal cost for this schedule is hence given as One billion, nine million, Eight hundred and thirty Three million, Three Hundred and Four naira.

Therefore we can represent the summary of the optimal schedule in tabular form below.

Table 4.22: ***Tabular result for Optimal PMS schedule in Tonnes*** .

	PHRC	KRPC	WRPC
ABA	212497	0	0
BENIN	0	0	249475
CALABAR	273995	0	0
ENUGU	264937	0	0
GUSAU	0	301059	0
GOMBE	0	68518	0
IBADAN	0	0	381393
ILORIN	0	0	127338
JOS	0	280509	0
KADUNA	0	215523	0
KANO	0	448675	0
ATLAS COVE	0	0	1053384
SATELLITE	0	0	143643
MOSIMI	0	0	490248
MAKURDI	69497	0	0
MAIDUGURI	0	222764	0
MINNA	0	145529	0
ORE	0	0	252729
PORT HARCOURT	366547	0	0
SULEJA	0	806232	0
WARRI	0	0	334230
YOLA	222580	0	0

Table 4.23: ***Tabular result for Optimal AGO schedule in Tonnes***

	PHRC	KRPC	WRPC
ABA	82989	0	0
BENIN	0	0	73835
CALABAR	75426	0	0
ENUGU	238614	0	0
GUSAU	0	84313	0
GOMBE	0	32342	0
IBADAN	0	0	43265
ILORIN	0	0	11129
JOS	0	82291	0
KADUNA	0	67416	0
KANO	0	158274	0
ATLAS COVE	0	0	176771
SATELLITE	0	0	24105
MOSIMI	0	0	69184
MAKURDI	35323	0	0
MAIDUGURI	0	40671	0
MINNA	0	25019	0
ORE	0	0	22272
PORT HARCOURT	283218	0	0
SULEJA	0	164861	0
WARRI	0	0	154984
YOLA	83732	0	0

.

Table 4.24: ***Tabular result for Optimal HHK schedule in Tonnes.***

	PHRC	KRPC	WRPC
ABA	128342	0	0
BENIN	0	0	106990
CALABAR	136877	0	0
ENUGU	135335	0	0
GUSAU	0	137583	0
GOMBE	0	33861	0
IBADAN	0	0	164346
ILORIN	0	0	57456
JOS	0	125776	0
KADUNA	0	114415	0
KANO	0	200161	0
ATLAS COVE	48853	0	373229
SATELLITE	57557	0	0
MOSIMI	0	0	214913
MAKURDI	34944	0	0
MAIDUGURI	0	113889	0
MINNA	0	64954	0
ORE	0	0	109279
PORT HARCOURT	188011	0	0
SULEJA	52426	279531	0
WARRI	0	0	172375
YOLA	104599	0	0

CHAPTER FIVE: FINDINGS, CONTRIBUTIONS, RECOMMENDATIONS AND CONCLUSIONS

5.1 Findings

Findings that were made from this research work carried out, are that;

- The expected demand of PMS from the depots across the country for the year 2016 according to the forecast made would be 5,111,580 metric tonnes, that of AGO would be 2,813,374 metric tonnes and HHK would be 2,578,188 metric tonnes.
- The expected supply or the least production capacity from PHRC should be 6703736 metric tonnes, for PMS, 844351 metric tonnes for AGO and 2011918 metric tonnes for HHK, also KRPC is expected to supply 3565817, 449123 and 1070169 metric tonnes of PMS, AGO and HHK respectively while WRPC would supply 3993715, 503017 and 1198590 metric tonnes for PMS, AGO and HHK respectively.
- The mathematical model developed was used produced the cost of optimal schedule shown in table 4.19, 4.20 and 4.21. That is, it shows the cost that would be incurred in the transportation of these products through pipeline in the year 2016.

5.2 Contribution to Knowledge

The aim of this research was to make a one year forecast of the demand and supply of major products(PMS, AGO and HHK) across the country and then develop a mathematical model that would minimize the cost of transporting these products from the three refineries(PHRC, KRPC and WRPC) to the twenty two depots across the country through pipeline.

The forecast was achieved by the use of exponential smoothening method of forecast and this was used to make a projection of an estimated amount in metric tonnes of the products to be circulated in the country. This technique used can be used to make yearly projections in the future.

The mathematical model developed and solved by *PYOMO* was used to develop an optimal schedule that showed the estimated cost of transporting these products through pipeline. This cost acquired would help the Planning and Budget Monitoring Department (PBMD) of the NNPC to determine the budget of transportation schedule through pipeline in the following year.

The forecast made and the mathematical model formed would help the government control the budget allocation to the oil and gas sector. Hence enable proper monitoring and formulation of optimal schedule of products should a supply node (refinery) fail temporarily.

5.3 Recommendations

Increasing supply and demand to accommodate uncertainty reveals the same pattern of distribution schedule but a change in the optimal solution. Besides, an increased production of HHK in Kaduna refinery should be provided and additional crude should be allocated and refined in Kaduna refinery in order to meet up all demand from catchment depots at minimum cost.

To ensure a steady flow of products and avoid scarcity in the nation as we recommend a pipeline system which is dynamic that is ensuring a connection between all depots and refineries, these connections would ensure the best cost and a more convenient transportation system.

Furthermore, proper data keeping and documentation by NNPC and PPMC is highly recommended as well as an accessible framework for research students is strongly recommended for further studies.

Finally, plant capacities of the nation's refineries should be adjusted to meet with the projected productions to satisfy the demand this way the country can cut off the importation of finished products.

5.4 Conclusion

This research work seeks to produce an effective and reliable forecast technique to produce a future yearly forecast with the exponential smoothening of a damping factor of 0.1, it has been able to show future projections which could be used for subsequent years so also the mathematical model developed produces an optimal schedule and the cost expected in the transportation of major products through pipeline, this model can also be used to determine future yearly cost to be incurred if the projected demand and supply for the following year is produced.

Future work can be to determine the need of rail transportation in the oil downstream sector and best location of depots in the country so as to get the best mode and an optimal schedule of transporting these products.

REFERENCES

Agbaeze, K.N. (2002) *Petroleum Pipeline Leakages* in PPMC Report for Chief Officers Mandatory Course 026, Lagos.

Aluko. S A and Ijere M.O (2004) "Petroleum and the Nigeria Economy" Awka: Africana publishing co.

Banaszak, S., Chakravorty, U. and Leung, P. S. (1999) Demand for ground transportation fuel and pricing policy in Asian Tigers: A comparative study of Korea and Taiwan, *The Energy Journal*, 20(2), 145-166.

Caputo, A. C., Pelagagge, P. M. and Scacchia, F. (2006) *Integrating transport systems in supply chain management software tools Industrial Management & Data Systems* page 103.

Dantzig,O. B 1963 "Large-Scale System Optimization: A Review," Operations Research Center, Recent Advances in Mathematical Programming, R. L. Graves and P. Wolfe, eds., McGraw-Hill, 1nc., New York, **1963**, pp.

Davis, P.S and Ray, T.L (1969), "A branch-Bound Algorithm for the Capacitated Facilities Location Problem." *Naval Research Logistics Quarterly, Vol. 16*, 331-344.

Ediger, V. S. and Akar, S. (2007) ARIMA forecasting of primary energy demand by fuel in Turkey, *Energy Policy*, 35(3), 1701-1708.

Eke M.N and, S.O. Enibe (2007) Optimal scheduling of petroleum products Distribution in Nigeria, *Nigerian Journal of Technology*, vol. 26 no.1.

Ellwein, K. B (1970), " The solid Transportation Problem*," Operations Research Quarterly, Vol. 10* No. 3,448-463.

Espey, M. (1996) Explaining the variation in elasticity estimates of gasoline demand in the United States: A meta-analysis, *Energy Economics*, 17(3), 315-323.

Gray, P. (1970), Exact Solution of the Fixed- Charge Transportation Problem," *Operations Research, Vol. 19, No. 6*, 1529-1538

Henry A.K and Miller S L (1997), *Transportation and Traffic Management*, New York: Alexander Hamilton institute.

Hitchcock, F.L. “The distribution of products from several sources to numerous localities”, J. Maths. Phy. , vol 20, (1941). Pp 224-230

Kantorovich, L. V. (1942). On mass transfer problem (in Russian). DoA'l. Acad. Na.uk SSSR 37, 199-201.

Klingman D and Russel R., Solving constrained transportation problems, operations research, vol 23, no.1, 1975, pp 91-106

Koopman, T.C. (1974) “Optimum utilization of transportation system” Proc. Intern statistics. Conf. Washington D.C., (1974)

Kumar .T, and Jain S.M (2009). : Comparison of optimization Technique in large scale Transportation Problem

Kupuloyi A. 0 (2000), *Proposals for effective marketing of Petroleum Product in Nigeria,* Unpublished project report, University of Jos.

Lon-Mu Liu (2001) *Data mining of time Series; An illustration Using Fast-Food Restaurants Franchise Data*. Department of Information and Decision Sciences, University of Illinois at Chicago, 2001

Marks, M. (1969), “An Introduction to Network Models used In Transportation Planning.” *Transportation Planning Models*, Elsevier Publishers, New York.

Murat Y. S. and Ceylan, H. (2006) Use of artificial neural networks for transport energy demand modelling, *Energy Policy*, 34(17), 3165–3172.

Ndu K. (1998) A Concise History of the Nigeria Oil Lndust, Ibada R. D company ‘ltd.

NNPC. (2015). Available at: http://www.nnpcgroup.com/AboutNNPC/CorporateInfo.aspx February 2016).

Ojogbo A.C (1999) *Problem of Nigeria Oil Industry*, Lagos Business times Publishers.

Olakumori K.0 (2000), *Transportation management,* Second Edition, Enugu: Giovanni publishers.

PPMC. (1994a). NNPC Profile, Pipelines and Products Marketing Company Limited (A subsidiary of NNPC) 1994.

PPMC. (1994b) Analysis of Petroleum Products lifting from NNPC Depots by sectors .January - December (1994-1995).

PPMC. (2015) Available at: http://www.nnpcgroup.com/nnpcbusiness/subsidiaries/ppmc.aspx (Accessed:10 February 2016).

Roy M.L and Gelders, L.F.(1980) "A Location-Allocation Problem in a Large Belgian Brewery," European Journal of Operation Research, 28, 196-206.

Sa, A and Cooper, W.W. (1969), *Management Models and Industrial Applications of Linear Programming*, John Wiley and sons, Inc., New York.

Saumis, S., Watson-Gandy, C. D. T. and Christofides, N. (1991) Distribution Management: Mathematical Modelling and Practical Analysis. Griffin, London.

Sharp. G , Jenny. B and Rob. B (1970).:Transportation Problem: A special case For Linear Programming.http://extension.oregonstate.edu/catalog/pdf/em/em8779-e.pdf.

Shetty C. M, (1959) Foundations of Optimization, Lecture Notes in Economics and Mathematical Systems, No. 122 ... 227–244, 1959.

Soland .M and Ross T. (1971) : A Branch And Bound Algorithm For The Generalized Assignment Problem. Mathematical Programming 8 (1971) 91-103. North-Holland Publishing Company.

Stringer W. and Harley. B (1957) Linear Programming: elementary geographical applications of the transportation problem

Tzeng, G.-H., Dušan, T., & Hwang, M.-J. (1995). Fuzzy bicriteria multi-index transportation problems for coal allocation planning of Taipower. *European Journal of Operational Research 95(1)*, 62-72 .

Williams. R.L(1962): Solving the transportation Problems. Management Sciences Vol.3.No.1.

APPENDICES

Appendix I : Linear Programming Model Translation With Parameters

MODEL FOR PMS Distribution Problem

Minimize

Sum_of_Transporting_Costs:

725 Route_KRPC→ABA + 1102 Route_KRPC→ATLAS_COVE + 507 Route_KRPC→BENIN + 1130 Route_KRPC→CALABAR + 569 Route_KRPC→ENUGU + 430 Route_KRPC→GOMBE + 260 Route_KRPC→GUSAU + 851 Route_KRPC→IBADAN + 1021 Route_KRPC→ILORIN + 165 Route_KRPC→JOS + 30 Route_KRPC→KADUNA + 223 Route_KRPC→KANO + 727 Route_KRPC→MAIDUGURI + 749 Route_KRPC→MAKURDI + 230 Route_KRPC→MINNA + 772 Route_KRPC→MOSIMI + 621 Route_KRPC→ORE + 973 Route_KRPC→PORT_HARCOURT + 1152 Route_KRPC→SATELLITE + 150 Route_KRPC→SULEJA + 857 Route_KRPC→WARRI + 1254 Route_KRPC→YOLA + 54 Route_PHRC→ABA + 880 Route_PHRC→ATLAS_COVE + 486 Route_PHRC→BENIN + 256 Route_PHRC→CALABAR + 210 Route_PHRC→ENUGU + 1209 Route_PHRC→GOMBE + 1039 Route_PHRC→GUSAU + 830 Route_PHRC→IBADAN + 1000 Route_PHRC→ILORIN + 944 Route_PHRC→JOS + 990 Route_PHRC→KADUNA_ + 1002 Route_PHRC→KANO + 1506 Route_PHRC→MAIDUGURI + 390 Route_PHRC→MAKURDI + 709 Route_PHRC→MINNA + 751 Route_PHRC→MOSIMI + 600 Route_PHRC→ORE + 25 Route_PHRC→PORT_HARCOURT + 883 Route_PHRC→SATELLITE + 629 Route_PHRC→SULEJA + 688 Route_PHRC→WARRI + 895 Route_PHRC→YOLA + 522 Route_WRPC→ABA + 603 Route_WRPC→ATLAS_COVE + 90 Route_WRPC→BENIN + 805 Route_WRPC→CALABAR + 366 Route_WRPC→ENUGU + 1027 Route_WRPC→GOMBE + 857 Route_WRPC→GUSAU + 434 Route_WRPC→IBADAN + 604 Route_WRPC→ILORIN + 762 Route_WRPC→JOS + 630 Route_WRPC→KADUNA_ + 820 Route_WRPC→KANO + 1324 Route_WRPC→MAIDUGURI + 546 Route_WRPC→MAKURDI + 527 Route_WRPC→MINNA + 355 Route_WRPC→MOSIMI + 204 Route_WRPC→ORE + 439 Route_WRPC→PORT_HARCOURT + 632 Route_WRPC→SATELLITE + 447 Route_WRPC→SULEJA + 15 Route_WRPC→WARRI + 1051 Route_WRPC→YOLA

Subject To

Sum_of_Products_into_***Depot***_ABA: Route_KRPC→ABA + Route_PHRC→ABA + Route_WRPC→ABA ≥ 156708.339245

Sum_of_Products_into_***Depot***_ATLAS_COVE: Route_KRPC→ATLAS_COVE + Route_PHRC→ATLAS_COVE + Route_WRPC→ATLAS_COVE ≥ 776831.836973

Sum_of_Products_into_***Depot***_BENIN: Route_KRPC→BENIN + Route_PHRC→BENIN + Route_WRPC→BENIN ≥ 183978.434378

Sum_of_Products_into_***Depot***_CALABAR: Route_KRPC→CALABAR + Route_PHRC→CALABAR + Route_WRPC→CALABAR ≥ 202061.394284

Sum_of_Products_into_***Depot***_ENUGU: Route_KRPC→ENUGU + Route_PHRC→ENUGU + Route_WRPC→ENUGU ≥ 195380.945305

Sum_of_Products_into_***Depot***_GOMBE: Route_KRPC→GOMBE + Route_PHRC→GOMBE + Route_WRPC→GOMBE ≥ 50529.7235458

Sum_of_Products_into_***Depot***_GUSAU: Route_KRPC→GUSAU + Route_PHRC→GUSAU + Route_WRPC→GUSAU ≥ 222020.223362

Sum_of_Products_into_***Depot***_IBADAN: Route_KRPC→IBADAN + Route_PHRC→IBADAN + Route_WRPC→IBADAN ≥ 281263.025839

Sum_of_Products_into_***Depot***_ILORIN: Route_KRPC→ILORIN + Route_PHRC→ILORIN + Route_WRPC→ILORIN ≥ 93907.3500627

Sum_of_Products_into_***Depot***_JOS: Route_KRPC→JOS + Route_PHRC→JOS + Route_WRPC→JOS ≥ 206865.127249

Sum_of_Products_into_***Depot***_KADUNA_: Route_KRPC→KADUNA_ Route_PHRC→KADUNA_ + Route_WRPC→KADUNA_ ≥ 158940.203508

Sum_of_Products_into_***Depot***_KANO: Route_KRPC→KANO + Route_PHRC→KANO + Route_WRPC→KANO ≥ 330881.529919

Sum_of_Products_into_***Depot***_MAIDUGURI: Route_KRPC→MAIDUGURI + Route_PHRC→MAIDUGURI + Route_WRPC→MAIDUGURI ≥ 164280.490100

Sum_of_Products_into_***Depot***_MAKURDI: Route_KRPC→MAKURDI + Route_PHRC→MAKURDI + Route_WRPC→MAKURDI ≥ 51251.7247315

Sum_of_Products_into_***Depot***_MINNA: Route_KRPC→MINNA + Route_PHRC→MINNA + Route_WRPC→MINNA ≥ 107321.954512

Sum_of_Products_into_***Depot***_MOSIMI: Route_KRPC→MOSIMI + Route_PHRC→MOSIMI+ Route_WRPC→MOSIMI ≥ 361540.028279

Sum_of_Products_into_***Depot***_ORE: Route_KRPC→ORE + Route_PHRC→ORE + Route_WRPC→ORE ≥ 186378.188273

Sum_of_Products_into_***Depot***_PORT_HARCOURT: Route_KRPC→PORT_HARCOURT + Route_PHRC→PORT_HARCOURT + Route_WRPC→PORT_HARCOURT ≥ **270314.733161**

Sum_of_Products_into_***Depot***_SATELLITE: Route_KRPC→SATELLITE + Route_PHRC→SATELLITE + Route_WRPC→SATELLITE **≥ 105931.614133**

Sum_of_Products_into_***Depot***_SULEJA: Route_KRPC→SULEJA + Route_PHRC→SULEJA + Route_WRPC→SULEJA **≥ 594566.411514**

Sum_of_Products_into_***Depot***_WARRI: Route_KRPC→WARRI + Route_PHRC→WARRI + Route_WRPC→WARRI ≥ **246482.269229**

Sum_of_Products_into_***Depot***_YOLA: Route_KRPC→YOLA + Route_PHRC→YOLA + Route_WRPC→YOLA ≥ **164144.258110**

Sum_of_Products_out_of_***Refinery***__KRPC:
Route_KRPC→ABA + Route_KRPC→ATLAS_COVE + Route_KRPC→BENIN + Route_KRPC→CALABAR + Route_KRPC→ENUGU + Route_KRPC→GOMBE + Route_KRPC→GUSAU + Route_KRPC→IBADAN + Route_KRPC→ILORIN + Route_KRPC→JOS + Route_KRPC→KADUNA_ + Route_KRPC→KANO + Route_KRPC→MAIDUGURI + Route_KRPC→MAKURDI + Route_KRPC→MINNA + Route_KRPC→MOSIMI + Route_KRPC→ORE + Route_KRPC→PORT_HARCOURT + Route_KRPC→SATELLITE + Route_KRPC→SULEJA + Route_KRPC→WARRI + Route_KRPC→YOLA ≤ **3565816.95680**

Sum_of_Products_out_of_***Refinery***__PHRC:
Route_PHRC→ABA + oute_PHRC→ATLAS_COVE + Route_PHRC→BENIN + Route_PHRC→CALABAR + Route_PHRC→ENUGU + Route_PHRC→GOMBE + Route_PHRC→GUSAU + Route_PHRC→IBADAN + Route_PHRC→ILORIN + Route_PHRC→JOS + Route_PHRC→KADUNA_ + Route_PHRC→KANO + Route_PHRC→MAIDUGURI + Route_PHRC→MAKURDI + Route_PHRC→MINNA + Route_PHRC→MOSIMI + Route_PHRC→ORE + Route_PHRC→PORT_HARCOURT + Route_PHRC→SATELLITE + Route_PHRC→SULEJA + Route_PHRC→WARRI + Route_PHRC→YOLA ≤ **6703735.87878**

Sum_of_Products_out_of_***Refinery***__WRPC:
Route_WRPC→ABA + Route_WRPC→ATLAS_COVE + Route_WRPC→BENIN + Route_WRPC→CALABAR + Route_WRPC→ENUGU + Route_WRPC→GOMBE + Route_WRPC→GUSAU + Route_WRPC→IBADAN + Route_WRPC→ILORIN + Route_WRPC→JOS + Route_WRPC→KADUNA_ + Route_WRPC→KANO + Route_WRPC→MAIDUGURI + Route_WRPC→MAKURDI + Route_WRPC→MINNA + Route_WRPC→MOSIMI + Route_WRPC→ORE + Route_WRPC→PORT_HARCOURT + Route_WRPC→SATELLITE + Route_WRPC→SULEJA + Route_WRPC→WARRI + Route_WRPC→YOLA ≤ **3993714.99162**

*** MODEL FOR AGO Distribution Problem ***

Minimize

Sum_of_Transporting_Costs:
725 Route_KRPC→ABA + 1102 Route_KRPC→ATLAS_COVE + 507 Route_KRPC→BENIN + 1130 Route_KRPC→CALABAR + 569 Route_KRPC→ENUGU + 430 Route_KRPC→GOMBE + 260 Route_KRPC→GUSAU + 851 Route_KRPC→IBADAN + 1021 Route_KRPC→ILORIN + 165 Route_KRPC→JOS + 30 Route_KRPC→KADUNA + 223 Route_KRPC→KANO + 727 Route_KRPC→MAIDUGURI + 749 Route_KRPC→MAKURDI + 230 Route_KRPC→MINNA + 772 Route_KRPC→MOSIMI + 621

Route_KRPC→ORE + 973 Route_KRPC→PORT_HARCOURT + 1152 Route_KRPC→SATELLITE + 150 Route_KRPC→SULEJA + 857 Route_KRPC→WARRI + 1254 Route_KRPC→YOLA + 54 Route_PHRC→ABA + 880 Route_PHRC→ATLAS_COVE + 486 Route_PHRC→BENIN + 256 Route_PHRC→CALABAR + 210 Route_PHRC→ENUGU + 1209 Route_PHRC→GOMBE + 1039 Route_PHRC→GUSAU + 830 Route_PHRC→IBADAN + 1000 Route_PHRC→ILORIN + 944 Route_PHRC→JOS + 990 Route_PHRC→KADUNA_ + 1002 Route_PHRC→KANO + 1506 Route_PHRC→MAIDUGURI + 390 Route_PHRC→MAKURDI + 709 Route_PHRC→MINNA + 751 Route_PHRC→MOSIMI + 600 Route_PHRC→ORE + 25 Route_PHRC→PORT_HARCOURT + 883 Route_PHRC→SATELLITE + 629 Route_PHRC→SULEJA + 688 Route_PHRC→WARRI + 895 Route_PHRC→YOLA + 522 Route_WRPC→ABA + 603 Route_WRPC→ATLAS_COVE + 90 Route_WRPC→BENIN + 805 Route_WRPC→CALABAR + 366 Route_WRPC→ENUGU + 1027 Route_WRPC→GOMBE + 857 Route_WRPC→GUSAU + 434 Route_WRPC→IBADAN + 604 Route_WRPC→ILORIN + 762 Route_WRPC→JOS + 630 Route_WRPC→KADUNA_ + 820 Route_WRPC→KANO + 1324 Route_WRPC→MAIDUGURI + 546 Route_WRPC→MAKURDI + 527 Route_WRPC→MINNA + 355 Route_WRPC→MOSIMI + 204 Route_WRPC→ORE + 439 Route_WRPC→PORT_HARCOURT + 632 Route_WRPC→SATELLITE + 447 Route_WRPC→SULEJA + 15 Route_WRPC→WARRI + 1051 Route_WRPC→YOLA

Subject To

Sum_of_Products_into_***Depot***_ABA: Route_KRPC→ABA + Route_PHRC→ABA + Route_WRPC→ABA ≤ 82989.1065825

Sum_of_Products_into_***Depot***_ATLAS_COVE: Route_KRPC→ATLAS_COVE + Route_PHRC→ATLAS_COVE + Route_WRPC→ATLAS_COVE ≤ 176770.684743

Sum_of_Products_into_***Depot***_BENIN: Route_KRPC→BENIN + Route_PHRC→BENIN + Route_WRPC→BENIN ≤ 73835.1379438

Sum_of_Products_into_***Depot***_CALABAR: Route_KRPC→CALABAR + Route_PHRC→CALABAR + Route_WRPC→CALABAR ≤ 75426.0145141

Sum_of_Products_into_***Depot***_ENUGU: Route_KRPC→ENUGU + Route_PHRC→ENUGU + Route_WRPC→ENUGU ≤ 238614.492451

Sum_of_Products_into_***Depot***_GOMBE: Route_KRPC→GOMBE + Route_PHRC→GOMBE + Route_WRPC→GOMBE ≤ 32341.7059424

Sum_of_Products_into_***Depot***_GUSAU: Route_KRPC→GUSAU + Route_PHRC→GUSAU + Route_WRPC→GUSAU ≤ 84313.4156357

Sum_of_Products_into_***Depot***_IBADAN: Route_KRPC→IBADAN + Route_PHRC→IBADAN + Route_WRPC→IBADAN ≤ 43264.9741603

Sum_of_Products_into_***Depot***_ILORIN: Route_KRPC→ILORIN + Route_PHRC→ILORIN + Route_WRPC→ILORIN ≤ 11128.6232474

Sum_of_Products_into_***Depot***_JOS: Route_KRPC→JOS + Route_PHRC→JOS + Route_WRPC→JOS ≤ 82291.3852565

Sum_of_Products_into_***Depot***_KADUNA_: Route_KRPC→KADUNA_ + Route_PHRC→KADUNA_ + Route_WRPC→KADUNA_ ≤ 67415.6275943

Sum_of_Products_into_***Depot***_KANO: Route_KRPC→KANO + Route_PHRC→KANO + Route_WRPC→KANO ≤ 158274.493527

Sum_of_Products_into_***Depot***_MAIDUGURI: Route_KRPC→MAIDUGURI + Route_PHRC→MAIDUGURI + Route_WRPC→MAIDUGURI ≤ 40670.5884595

Sum_of_Products_into_***Depot***_MAKURDI: Route_KRPC→MAKURDI + Route_PHRC→MAKURDI + Route_WRPC→MAKURDI ≤ 35323.3000589

Sum_of_Products_into_***Depot***_MINNA: Route_KRPC→MINNA + Route_PHRC→MINNA + Route_WRPC→MINNA ≤ 25018.8623213

Sum_of_Products_into_***Depot***_MOSIMI: Route_KRPC→MOSIMI + Route_PHRC→MOSIMI + Route_WRPC→MOSIMI ≤ 69183.6053348

Sum_of_Products_into_***Depot***_ORE: Route_KRPC→ORE + Route_PHRC→ORE + Route_WRPC→ORE ≤ 22271.8845791

Sum_of_Products_into_***Depot***_PORT_HARCOURT: Route_KRPC→PORT_HARCOURT + Route_PHRC→PORT_HARCOURT + Route_WRPC→PORT_HARCOURT ≤ 283218.298249

Sum_of_Products_into_***Depot***_SATELLITE: Route_KRPC→SATELLITE + Route_PHRC→SATELLITE + Route_WRPC→SATELLITE ≤ 24105.0933740

Sum_of_Products_into_***Depot***_SULEJA: Route_KRPC→SULEJA + Route_PHRC→SULEJA + Route_WRPC→SULEJA ≤ 164861.417559

Sum_of_Products_into_***Depot***_WARRI: Route_KRPC→WARRI + Route_PHRC→WARRI + Route_WRPC→WARRI ≤ 154983.840954

Sum_of_Products_into_***Depot***_YOLA: Route_KRPC→YOLA + Route_PHRC→YOLA + Route_WRPC→YOLA ≤ 83732.0797068

Sum_of_Products_out_of_***Refinery***_KRPC: Route_KRPC→ABA + Route_KRPC→ATLAS_COVE + Route_KRPC→BENIN + Route_KRPC→CALABAR + Route_KRPC→ENUGU + Route_KRPC→GOMBE + Route_KRPC→GUSAU + Route_KRPC→IBADAN + Route_KRPC→ILORIN + Route_KRPC→JOS + Route_KRPC→KADUNA_ + Route_KRPC→KANO + Route_KRPC→MAIDUGURI + Route_KRPC→MAKURDI + Route_KRPC→MINNA + Route_KRPC→MOSIMI + Route_KRPC→ORE +

Route_KRPC→PORT_HARCOURT + Route_KRPC→SATELLITE + Route_KRPC→SULEJA + Route_KRPC→WARRI + Route_KRPC→YOLA ≤ 703343.565450

Sum_of_Products_out_of_***Refinery***_PHRC:
Route_PHRC→ABA + oute_PHRC→ATLAS_COVE + Route_PHRC→BENIN + Route_PHRC→CALABAR + Route_PHRC→ENUGU + Route_PHRC→GOMBE + Route_PHRC→GUSAU + Route_PHRC→IBADAN + Route_PHRC→ILORIN + Route_PHRC→JOS + Route_PHRC→KADUNA_ + Route_PHRC→KANO + Route_PHRC→MAIDUGURI + Route_PHRC→MAKURDI + Route_PHRC→MINNA + Route_PHRC→MOSIMI + Route_PHRC→ORE + Route_PHRC→PORT_HARCOURT + Route_PHRC→SATELLITE + Route_PHRC→SULEJA + Route_PHRC→WARRI + Route_PHRC→YOLA ≤ 1322285.90305

Sum_of_Products_out_of_***Refinery***_WRPC: Route_WRPC→ABA + Route_WRPC→ATLAS_COVE + Route_WRPC→BENIN + Route_WRPC→CALABAR + Route_WRPC→ENUGU + Route_WRPC→GOMBE + Route_WRPC→GUSAU + Route_WRPC→IBADAN + Route_WRPC→ILORIN + Route_WRPC→JOS + Route_WRPC→KADUNA_ + Route_WRPC→KANO + Route_WRPC→MAIDUGURI + Route_WRPC→MAKURDI + Route_WRPC→MINNA + Route_WRPC→MOSIMI + Route_WRPC→ORE + Route_WRPC→PORT_HARCOURT + Route_WRPC→SATELLITE + Route_WRPC→SULEJA + Route_WRPC→WARRI + Route_WRPC→YOLA ≤ 787744.793304

*** MODEL FOR HHK Distribution Problem ***

Minimize

Sum_of_Transporting_Costs:
725 Route_KRPC→ABA + 1102 Route_KRPC→ATLAS_COVE + 507 Route_KRPC→BENIN + 1130 Route_KRPC→CALABAR + 569 Route_KRPC→ENUGU + 430 Route_KRPC→GOMBE + 260 Route_KRPC→GUSAU + 851 Route_KRPC→IBADAN + 1021 Route_KRPC→ILORIN + 165 Route_KRPC→JOS + 30 Route_KRPC→KADUNA + 223 Route_KRPC→KANO + 727 Route_KRPC→MAIDUGURI + 749 Route_KRPC→MAKURDI + 230 Route_KRPC→MINNA + 772 Route_KRPC→MOSIMI + 621 Route_KRPC→ORE + 973 Route_KRPC→PORT_HARCOURT + 1152 Route_KRPC→SATELLITE + 150 Route_KRPC→SULEJA + 857 Route_KRPC→WARRI + 1254 Route_KRPC→YOLA + 54 Route_PHRC→ABA + 880 Route_PHRC→ATLAS_COVE + 486 Route_PHRC→BENIN + 256 Route_PHRC→CALABAR + 210 Route_PHRC→ENUGU + 1209 Route_PHRC→GOMBE + 1039 Route_PHRC→GUSAU + 830 Route_PHRC→IBADAN + 1000 Route_PHRC→ILORIN + 944 Route_PHRC→JOS + 990 Route_PHRC→KADUNA_ + 1002 Route_PHRC→KANO + 1506 Route_PHRC→MAIDUGURI + 390 Route_PHRC→MAKURDI + 709 Route_PHRC→MINNA + 751 Route_PHRC→MOSIMI + 600 Route_PHRC→ORE + 25 Route_PHRC→PORT_HARCOURT + 883 Route_PHRC→SATELLITE + 629 Route_PHRC→SULEJA + 688 Route_PHRC→WARRI + 895 Route_PHRC→YOLA + 522 Route_WRPC→ABA + 603 Route_WRPC→ATLAS_COVE + 90 Route_WRPC→BENIN + 805 Route_WRPC→CALABAR + 366 Route_WRPC→ENUGU + 1027 Route_WRPC→GOMBE + 857 Route_WRPC→GUSAU + 434

Route_WRPC→IBADAN + 604 Route_WRPC→ILORIN + 762 Route_WRPC→JOS + 630 Route_WRPC→KADUNA_ + 820 Route_WRPC→KANO + 1324 Route_WRPC→MAIDUGURI + 546 Route_WRPC→MAKURDI + 527 Route_WRPC→MINNA + 355 Route_WRPC→MOSIMI + 204 Route_WRPC→ORE + 439 Route_WRPC→PORT_HARCOURT + 632 Route_WRPC→SATELLITE + 447 Route_WRPC→SULEJA + 15 Route_WRPC→WARRI + 1051 Route_WRPC→YOLA

Subject To

Sum_of_Products_into_BarABA: Route_KRPC→ABA + Route_PHRC→ABA + Route_WRPC→ABA ≤ 104854.550552

Sum_of_Products_into_BarATLAS_COVE: Route_KRPC→ATLAS_COVE + Route_PHRC→ATLAS_COVE + Route_WRPC→ATLAS_COVE ≤ 344838.286104

Sum_of_Products_into_BarBENIN: Route_KRPC→BENIN + Route_PHRC→BENIN + Route_WRPC→BENIN ≤ 87410.0936121

Sum_of_Products_into_BarCALABAR: Route_KRPC→CALABAR + Route_PHRC→CALABAR + Route_WRPC→CALABAR ≤ 111827.921459

Sum_of_Products_into_BarENUGU: Route_KRPC→ENUGU + Route_PHRC→ENUGU + Route_WRPC→ENUGU ≤ 110567.857650

Sum_of_Products_into_BarGOMBE: Route_KRPC→GOMBE + Route_PHRC→GOMBE + Route_WRPC→GOMBE ≤ 27664.5084400

Sum_of_Products_into_BarGUSAU: Route_KRPC→GUSAU + Route_PHRC→GUSAU + Route_WRPC→GUSAU ≤ 112404.179327

Sum_of_Products_into_BarIBADAN: Route_KRPC→IBADAN + Route_PHRC→IBADAN + Route_WRPC→IBADAN ≤ 134269.996361

Sum_of_Products_into_BarILORIN: Route_KRPC→ILORIN + Route_PHRC→ILORIN + Route_WRPC→ILORIN ≤ 46941.3088783

Sum_of_Products_into_BarJOS: Route_KRPC→JOS + Route_PHRC→JOS + Route_WRPC→JOS ≤ 102758.061420

Sum_of_Products_into_BarKADUNA_: Route_KRPC→KADUNA_ + Route_PHRC→KADUNA_ + Route_WRPC→KADUNA_ ≤ 93476.0236420

Sum_of_Products_into_BarKANO: Route_KRPC→KANO + Route_PHRC→KANO + Route_WRPC→KANO ≤ 163530.067008

Sum_of_Products_into_BarMAIDUGURI: Route_KRPC→MAIDUGURI + Route_PHRC→MAIDUGURI + Route_WRPC→MAIDUGURI ≤ 93046.5732071

Sum_of_Products_into_BarMAKURDI: Route_KRPC→MAKURDI + Route_PHRC→MAKURDI + Route_WRPC→MAKURDI ≤ 28549.0071728

Sum_of_Products_into_BarMINNA: Route_KRPC→MINNA + Route_PHRC→MINNA + Route_WRPC→MINNA ≤ 53067.0282369

Sum_of_Products_into_BarMOSIMI: Route_KRPC→MOSIMI + Route_PHRC→MOSIMI + Route_WRPC→MOSIMI ≤ 175582.784603

Sum_of_Products_into_BarORE: Route_KRPC→ORE + Route_PHRC→ORE + Route_WRPC→ORE ≤ 89280.5087430

Sum_of_Products_into_BarPORT_HARCOURT: Route_KRPC→PORT_HARCOURT + Route_PHRC→PORT_HARCOURT + Route_WRPC→PORT_HARCOURT ≤ 153603.506550

Sum_of_Products_into_BarSATELLITE: Route_KRPC→SATELLITE + Route_PHRC→SATELLITE + Route_WRPC→SATELLITE ≤ 47023.4026505

Sum_of_Products_into_BarSULEJA: Route_KRPC→SULEJA + Route_PHRC→SULEJA + Route_WRPC→SULEJA ≤ 271206.830776

Sum_of_Products_into_BarWARRI: Route_KRPC→WARRI + Route_PHRC→WARRI + Route_WRPC→WARRI ≤ 140829.173518

Sum_of_Products_into_BarYOLA: Route_KRPC→YOLA + Route_PHRC→YOLA + Route_WRPC→YOLA ≤ 85456.3554060

Sum_of_Products_out_of_***REFINERY***_KRPC: Route_KRPC→ABA + Route_KRPC→ATLAS_COVE + Route_KRPC→BENIN + Route_KRPC→CALABAR + Route_KRPC→ENUGU + Route_KRPC→GOMBE + Route_KRPC→GUSAU + Route_KRPC→IBADAN + Route_KRPC→ILORIN + Route_KRPC→JOS + Route_KRPC→KADUNA_ + Route_KRPC→KANO + Route_KRPC→MAIDUGURI + Route_KRPC→MAKURDI + Route_KRPC→MINNA + Route_KRPC→MOSIMI + Route_KRPC→ORE + Route_KRPC→PORT_HARCOURT + Route_KRPC→SATELLITE + Route_KRPC→SULEJA + Route_KRPC→WARRI + Route_KRPC→YOLA ≤ 1070169.30735

Sum_of_Products_out_of_***REFINERY***_PHRC: Route_PHRC→ABA + Route_PHRC→ATLAS_COVE + Route_PHRC→BENIN + Route_PHRC→CALABAR + Route_PHRC→ENUGU + Route_PHRC→GOMBE + Route_PHRC→GUSAU + Route_PHRC→IBADAN + Route_PHRC→ILORIN + Route_PHRC→JOS +

Route_PHRC→KADUNA_ + Route_PHRC→KANO + Route_PHRC→MAIDUGURI + Route_PHRC→MAKURDI + Route_PHRC→MINNA + Route_PHRC→MOSIMI + Route_PHRC→ORE + Route_PHRC→PORT_HARCOURT + Route_PHRC→SATELLITE + Route_PHRC→SULEJA + Route_PHRC→WARRI + Route_PHRC→YOLA ≤ 2011918.29782

Sum_of_Products_out_of_***REFINERY***_WRPC: Route_WRPC→ABA + Route_WRPC→ATLAS_COVE + Route_WRPC→BENIN + Route_WRPC→CALABAR + Route_WRPC→ENUGU + Route_WRPC→GOMBE + Route_WRPC→GUSAU + Route_WRPC→IBADAN + Route_WRPC→ILORIN + Route_WRPC→JOS + Route_WRPC→KADUNA_ + Route_WRPC→KANO + Route_WRPC→MAIDUGURI + Route_WRPC→MAKURDI + Route_WRPC→MINNA + Route_WRPC→MOSIMI + Route_WRPC→ORE + Route_WRPC→PORT_HARCOURT + Route_WRPC→SATELLITE + Route_WRPC→SULEJA + Route_WRPC→WARRI + Route_WRPC→YOLA ≤ 1198589.62423

Bounds

0 ≤ Route_KRPC→ABA

0 ≤ Route_KRPC→ATLAS_COVE

0 ≤ Route_KRPC→BENIN

0 ≤ Route_KRPC→CALABAR

0 ≤ Route_KRPC→ENUGU

0 ≤ Route_KRPC→GOMBE

0 ≤ Route_KRPC→GUSAU

0 ≤ Route_KRPC→IBADAN

0 ≤ Route_KRPC→ILORIN

0 ≤ Route_KRPC→JOS

0 ≤ Route_KRPC→KADUNA_

0 ≤ Route_KRPC→KANO

0 ≤ Route_KRPC→MAIDUGURI

0 ≤ Route_KRPC→MAKURDI

0 ≤ Route_KRPC→MINNA

0 ≤ Route_KRPC→MOSIMI

0 ≤ Route_KRPC→ORE

0 ≤ Route_KRPC→PORT_HARCOURT

0 ≤ Route_KRPC→SATELLITE

$0 \leq$ Route_KRPC→SULEJA

$0 \leq$ Route_KRPC→WARRI

$0 \leq$ Route_KRPC→YOLA

$0 \leq$ Route_PHRC→ABA

$0 \leq$ Route_PHRC→ATLAS_COVE

$0 \leq$ Route_PHRC→BENIN

$0 \leq$ Route_PHRC→CALABAR

$0 \leq$ Route_PHRC→ENUGU

$0 \leq$ Route_PHRC→GOMBE

$0 \leq$ Route_PHRC→GUSAU

$0 \leq$ Route_PHRC→IBADAN

$0 \leq$ Route_PHRC→ILORIN

$0 \leq$ Route_PHRC→JOS

$0 \leq$ Route_PHRC→KADUNA_

$0 \leq$ Route_PHRC→KANO

$0 \leq$ Route_PHRC→MAIDUGURI

$0 \leq$ Route_PHRC→MAKURDI

$0 \leq$ Route_PHRC→MINNA

$0 \leq$ Route_PHRC→MOSIMI

$0 \leq$ Route_PHRC→ORE

$0 \leq$ Route_PHRC→PORT_HARCOURT

$0 \leq$ Route_PHRC→SATELLITE

$0 \leq$ Route_PHRC→SULEJA

$0 \leq$ Route_PHRC→WARRI

$0 \leq$ Route_PHRC→YOLA

$0 \leq$ Route_WRPC→ABA

$0 \leq$ Route_WRPC→ATLAS_COVE

$0 \leq$ Route_WRPC→BENIN

$0 \leq$ Route_WRPC→CALABAR

$0 \leq$ Route_WRPC→ENUGU

$0 \leq$ Route_WRPC→GOMBE

$0 \leq$ Route_WRPC→GUSAU

$0 \leq$ Route_WRPC→IBADAN

$0 \leq$ Route_WRPC→ILORIN

$0 \leq$ Route_WRPC→JOS

$0 \leq$ Route_WRPC→KADUNA_

$0 \leq$ Route_WRPC→KANO

$0 \leq$ Route_WRPC→MAIDUGURI

$0 \leq$ Route_WRPC→MAKURDI

$0 \leq$ Route_WRPC→MINNA

$0 \leq$ Route_WRPC→MOSIMI

$0 \leq$ Route_WRPC→ORE

$0 \leq$ Route_WRPC→PORT_HARCOURT

$0 \leq$ Route_WRPC→SATELLITE

$0 \leq$ Route_WRPC→SULEJA

$0 \leq$ Route_WRPC→WARRI

$0 \leq$ Route_WRPC→YOLA

Generals

Route_KRPC→ABA

Route_KRPC→ATLAS_COVE

Route_KRPC→BENIN

Route_KRPC→CALABAR

Route_KRPC→ENUGU

Route_KRPC→GOMBE

Route_KRPC→GUSAU

Route_KRPC→IBADAN

Route_KRPC→ILORIN

Route_KRPC→JOS

Route_KRPC→KADUNA_

Route_KRPC→KANO

Route_KRPC→MAIDUGURI

Route_KRPC→MAKURDI

Route_KRPC→MINNA

Route_KRPC→MOSIMI

Route_KRPC→ORE

Route_KRPC→PORT_HARCOURT

Route_KRPC→SATELLITE

Route_KRPC→SULEJA

Route_KRPC→WARRI

Route_KRPC→YOLA

Route_PHRC→ABA

Route_PHRC→ATLAS_COVE

Route_PHRC→BENIN

Route_PHRC→CALABAR

Route_PHRC→ENUGU

Route_PHRC→GOMBE

Route_PHRC→GUSAU

Route_PHRC→IBADAN

Route_PHRC→ILORIN

Route_PHRC→JOS

Route_PHRC→KADUNA_

Route_PHRC→KANO

Route_PHRC→MAIDUGURI

Route_PHRC→MAKURDI

Route_PHRC→MINNA

Route_PHRC→MOSIMI

Route_PHRC→ORE

Route_PHRC→PORT_HARCOURT

Route_PHRC→SATELLITE

Route_PHRC→SULEJA

Route_PHRC→WARRI

Route_PHRC→YOLA

Route_WRPC→ABA

Route_WRPC→ATLAS_COVE

Route_WRPC→BENIN

Route_WRPC→CALABAR

Route_WRPC→ENUGU

Route_WRPC→GOMBE

Route_WRPC→GUSAU

Route_WRPC→IBADAN

Route_WRPC→ILORIN

Route_WRPC→JOS

Route_WRPC→KADUNA_

Route_WRPC→KANO

Route_WRPC→MAIDUGURI

Route_WRPC→MAKURDI

Route_WRPC→MINNA

Route_WRPC→MOSIMI

Route_WRPC→ORE

Route_WRPC→PORT_HARCOURT

Route_WRPC→SATELLITE

Route_WRPC→SULEJA

Route_WRPC→WARRI

Route_WRPC→YOLA

End

Appendix II : Pyomo Script For Abstract Model Used

```
#from pyomo.environ import * # For Pyomo 4.0 & later
from coopr.pyomo import * # For earlier versions

model = AbstractModel()

## Define sets
model.Warehouses = Set()
model.Bars = Set()

## Define parameters
model.supply = Param(model.Warehouses)
model.demand = Param(model.Bars)
model.costs = Param(model.Warehouses, model.Bars)

## Define variables
model.flow = Var(model.Warehouses, model.Bars, within = NonNegativeReals)

## Define Objective Function
def costRule(model):
   return sum(
       model.costs[n,i] * model.flow[n,i]
       for n in model.Warehouses
       for i in model.Bars
    )
model.SolverResult=Objective(rule=costRule)

## Satisfy demands
def minDemandRule(model,bar):
    return sum(model.flow[i, bar] for i in model.Warehouses) >= model.demand[bar]
model.demandConstraint = Constraint(model.Bars, rule=minDemandRule)

## Satisfy supplies
def maxSupplyRule(model,warehouse):
    return sum(model.flow[warehouse, j] for j in model.Bars) <= model.supply[warehouse]
model.supplyConstraint = Constraint(model.Warehouses, rule=maxSupplyRule)
```

Appendix III: Premium Motor Spirit Demand By State

PREMIUM MOTOR SPIRIT DEMAND BY STATE									*(000.LITRES)*
States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	65351.22	78067.95	88720.75	106279.69	88236.93	120236.36	105919.76	96330.42	96427.71
Adamawa	97361.21	87398.82	102005.72	163095.62	162817.33	183290.33	165123.07	162062.70	162095.10
Akwa-Ibom	49993.16	68653.61	72161.30	94017.18	96688.25	173140.90	116423.39	162854.58	162395.86
Anambra	33146.58	118311.83	76315.70	92481.29	112078.59	140263.15	181840.02	184249.21	184220.93
Bauchi	76194.13	72434.52	80436.16	243148.74	252709.33	237098.62	208745.20	148035.95	148645.89
Bayelsa	9982.06	4443.43	15276.31	47154.33	86862.32	144589.04	50076.52	56270.95	56218.39
Benue	75041.36	87300.83	87342.04	107767.68	128152.20	160131.58	83263.38	69148.83	69297.63
Borno	79224.58	74834.19	91442.73	140119.72	180834.10	167453.04	192989.23	157699.78	158050.14
Cross-Rivers	124197.84	113472.78	132337.63	133611.94	123399.28	176034.95	93842.57	112233.86	112058.12
Delta	224659.37	306464.90	232366.79	251521.66	232876.05	356224.36	238140.45	278632.86	278239.62
Ebonyi	8573.12	17808.51	41870.75	89575.04	30711.92	52274.66	25583.04	33456.34	33380.26
Edo	180015.17	151659.77	167589.35	179844.60	192008.76	236129.36	179374.10	250774.08	250065.71
Ekiti	44827.93	45786.74	54820.97	85797.83	91759.72	117377.91	127933.72	132429.84	132383.80
Enugu	86204.28	121017.76	92153.22	123609.84	108982.86	168076.14	70584.24	46896.80	47143.37
Gombe	42701.58	87430.76	67185.32	95045.42	149661.33	178694.48	104464.99	67743.18	68117.79
Imo	81277.86	82596.21	76928.33	88695.16	115709.93	175654.33	116168.15	115907.90	115916.39
Jigawa	52907.49	83808.90	76141.36	111183.95	106197.69	91091.47	88719.18	53997.67	54345.14
Kaduna	221201.69	269799.83	294327.58	409852.10	524570.54	577075.87	284013.92	213877.45	214608.07
Kano	276832.93	298166.98	366545.52	360912.24	466995.12	346548.37	308809.92	269272.27	269671.54
Katsina	68464.40	108349.13	114339.14	297332.70	269854.95	251833.10	227682.99	121900.03	122960.30
Kebbi	40243.69	49703.09	99046.01	121477.48	212629.61	193936.51	212572.04	122132.34	123034.89
Kogi	60317.91	194670.25	189747.47	236012.15	156250.34	229357.00	107298.50	75186.02	75519.28
Kwara	160758.48	105144.23	104710.03	129061.01	134052.01	114679.82	160679.85	126741.80	127076.60
Lagos	2440565.82	1596360.59	1474672.11	1667363.46	877521.15	449752.34	1230717.53	1197190.58	1197448.19
Nasarawa	131835.09	108914.63	69590.52	129212.63	201681.29	279147.20	152408.53	55043.37	56029.61
Niger	270321.90	492736.46	277652.34	339086.64	216895.96	194236.31	184257.34	144763.85	145159.81
Ogun	496713.60	292508.98	294144.17	366870.96	193975.52	212395.62	426979.56	371177.38	371713.93
Ondo	184169.67	139030.76	110117.61	204420.87	188471.36	196257.33	163646.49	119525.46	119969.93
Osun	134014.58	105040.85	127282.06	261641.62	133041.33	138058.48	250841.30	115801.28	117140.40
Oyo	468365.13	384528.64	346382.48	485617.43	285938.96	167476.14	416437.01	380976.46	381306.29
Plateau	106077.54	149581.67	129725.42	141992.35	163402.50	207390.51	138516.69	131075.68	131156.93
Rivers	435227.52	488342.96	379805.28	448485.07	378424.17	470161.07	379154.50	366210.25	366348.71
Sokoto	39362.96	96991.06	78352.65	98228.34	132072.71	156339.60	131804.46	107413.36	107659.70
Taraba	26104.35	55558.90	48599.78	52852.01	85398.17	102809.68	87756.01	59897.45	60177.53
Yobe	72287.44	127088.92	118962.22	117367.46	149509.59	98560.55	120910.82	63346.83	63920.29
Zamfara	38949.40	82123.69	75951.88	122361.17	133537.64	116054.20	63173.09	69386.16	69329.34
Abuja	722288.97	460595.87	621528.29	947372.62	878444.49	1011201.62	625275.45	673800.99	673354.20
DEMAND FOR PMS PRODUCT SINCE 2007.						*SOURCE NNPC PMI FIGURES.*			

Appendix IV: Automated Gas Oil (AGO) Demand By State

AUTOMATED GAS OIL DEMAND BY STATE									*(000.LITRES)*
States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	27033.86	15544.58	8198.52	24197.71	36680.24	21386.45	22811.24	93687.82	92978.93
Adamawa	9350.69	19236.31	7083.41	23920.31	26075.21	11924.19	18332.41	96653.03	95869.19
Akwa-Ibom	5101.99	12343.48	4329.13	12273.36	30337.53	13184.52	16184.59	65225.37	64734.67
Anambra	5032.08	5509.30	4396.15	15677.30	26024.70	7470.04	7371.88	56641.40	56148.73
Bauchi	5694.82	17160.62	3495.99	30253.42	47688.07	12461.42	13196.24	86012.91	85284.71
Bayelsa	1476.29	7600.55	771.96	5059.10	24980.22	2451.24	3978.68	89699.82	88842.48
Benue	2940.43	66404.08	4159.95	12628.72	28453.38	8485.94	11816.23	68282.03	67717.06
Borno	7449.48	7849.37	6562.32	21763.77	39338.49	8512.74	10147.72	77809.67	77132.91
Cross-Rivers	14552.07	11117.56	5390.03	14750.23	29756.27	16760.84	18665.65	61678.32	61248.01
Delta	44985.06	48205.72	67695.02	84773.73	109818.15	79499.43	84740.50	243865.68	242273.94
Ebonyi	4327.39	66812.35	3637.28	9403.94	27665.15	105347.34	114746.74	116671.27	116651.01
Edo	22063.85	38005.68	28667.87	47241.46	106539.70	43266.94	45717.01	109459.83	108822.22
Ekiti	2611.10	274934.81	1617.07	4419.47	20164.88	3176.62	2242.34	52177.42	51678.18
Enugu	16606.05	21935.40	36055.51	18791.81	32539.05	25636.26	30215.35	99757.10	99061.24
Gombe	4041.96	10955.64	6457.80	33679.93	38858.86	12057.52	12988.36	63428.80	62924.33
Imo	11701.86	14842.74	10054.87	14033.06	34989.57	18791.43	21379.35	95307.05	94567.53
Jigawa	4019.06	1055.13	2005.10	6764.94	21548.20	3154.10	4554.36	50762.83	50300.62
Kaduna	21701.66	94218.37	33922.59	114688.19	139256.42	40471.76	41233.42	137815.29	136849.49
Kano	20290.06	58579.67	49345.36	68804.28	60137.29	73255.66	80378.07	106032.84	105775.56
Katsina	3590.00	4254.35	3310.95	27836.31	67736.72	5045.07	4468.78	43155.76	42769.01
Kebbi	1805.55	3649.84	3232.29	16693.35	28459.32	4679.63	7270.66	69608.32	68984.71
Kogi	1250.86	5932.36	6902.38	9727.59	32431.34	5768.74	5870.42	63983.80	63402.68
Kwara	15552.50	4930.47	5286.79	18772.26	33622.92	5153.57	4222.63	43675.17	43280.76
Lagos	140284.64	139293.73	100936.96	211459.58	168583.92	138396.51	147569.63	94414.08	94944.75
Nasarawa	7331.48	3352.81	1776.87	13890.66	28325.50	4847.80	7263.48	69517.50	68894.74
Niger	6846.56	7225.61	6087.04	21392.62	31724.43	11034.76	9579.72	77112.01	76436.85
Ogun	10460.16	28399.18	29793.13	25530.85	43378.43	27430.91	29477.47	89368.29	88769.19
Ondo	3579.78	8831.00	3190.53	11513.95	27765.21	7712.08	7183.72	46260.15	45869.46
Osun	3635.25	2589.73	2678.68	15229.74	27760.44	2980.25	3645.06	56025.46	55501.62
Oyo	29588.54	26013.39	21661.24	44214.91	53092.40	24988.66	25903.36	87577.75	86960.94
Plateau	25827.17	16632.65	14832.14	22310.17	34474.90	18702.26	20198.80	87458.55	86785.82
Rivers	111206.99	168920.61	118064.18	208185.82	127138.61	172406.89	189441.40	235956.96	235490.05
Sokoto	7254.24	16400.69	7028.88	14407.56	17750.43	21461.02	23258.58	49029.43	48771.53
Taraba	682.99	2712.09	4111.35	8122.60	14343.79	3548.32	6011.97	54436.94	53952.46
Yobe	1196.90	3186.52	4018.99	13600.21	18604.99	4236.81	4814.38	56333.73	55818.49
Zamfara	4282.23	4093.15	1715.18	12748.72	22184.09	6387.69	7317.60	52241.75	51792.43
Abuja	20927.42	34473.60	29943.37	77599.55	92235.82	41147.36	49107.20	172039.59	170809.52
DEMAND FOR AGO PRODUCT SINCE 2007								*SOURCE NNPC PMI FIGURES*	

Appendix V: House Hold Kerosene (HHK) Demand By State

HOUSE HOLD KEROSENE DEMAND BY STATE							*(000.LITRES)*		
States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	54224.22	29461.78	26624.06	30304.73	39703.85	46093.03	53894.02	69893.57	69732.79
Adamawa	34337.59	12008.86	13334.97	45950.08	55164.86	67364.51	77923.88	72842.68	72892.42
Akwa-Ibom	22822.51	14185.87	8634.15	27208.31	40263.48	64595.84	54941.82	82843.62	82565.54
Anambra	11178.13	18351.24	10787.45	43785.59	53652.25	50835.53	85812.85	83102.80	83126.40
Bauchi	29370.54	11282.05	9125.15	54549.79	73781.44	86181.43	98509.78	65610.58	65938.32
Bayelsa	3399.91	860.35	2110.38	53839.06	44356.72	53922.94	23631.81	39826.30	39667.37
Benue	10774.04	308171.30	9345.76	35036.40	53277.67	53207.96	39293.15	34844.47	34890.35
Borno	6161.08	6163.61	68424.28	48791.43	57391.07	60299.06	91074.31	77112.66	77249.19
Cross-Rivers	55661.02	15001.87	13132.48	65626.03	63936.69	62907.27	44285.62	54734.13	54631.51
Delta	17325.70	308353.49	341349.57	399206.05	241024.26	143438.13	112381.80	133174.05	132969.33
Ebonyi	2800.25	7285.30	8817.88	19884.60	31918.60	22675.90	12073.00	23164.00	23054.16
Edo	37448.79	116559.65	79057.00	189785.44	174986.09	86153.37	84649.15	107411.80	107184.41
Ekiti	1974.90	6523.02	23773.52	30446.12	43995.51	44814.59	60373.71	57190.31	57220.59
Enugu	42894.59	23143.52	31408.32	41101.38	44821.37	62035.66	33309.69	29144.45	29188.96
Gombe	18806.90	11932.15	14303.24	40852.78	66981.49	68007.48	49298.49	33541.98	33701.42
Imo	60525.16	30263.50	12302.46	38558.89	45703.50	62903.72	54821.37	58830.83	58791.53
Jigawa	1690.74	4861.01	13084.39	25009.62	29264.67	35164.64	41867.82	27172.26	27318.54
Kaduna	37109.70	160182.00	55980.04	261690.26	218980.84	216310.83	134030.14	113942.81	114151.91
Kano	74872.70	45370.32	89322.10	121323.04	77062.48	127428.93	145731.72	114118.43	114432.69
Katsina	26630.48	14728.27	19020.81	47362.23	60950.76	83829.82	107446.78	57094.34	57595.48
Kebbi	159885.38	18343.71	15222.69	24018.07	41948.25	67713.95	100315.72	56064.80	56504.02
Kogi	201.35	16225.67	78109.50	53195.71	64071.34	79004.50	50635.66	37227.72	37364.62
Kwara	2388.86	15253.87	25389.50	32649.36	50214.44	45310.73	75827.07	57133.95	57317.83
Lagos	295842.48	218619.71	439416.50	380722.23	269889.25	191787.06	580792.79	478102.58	479090.66
Nasarawa	11093.28	11912.48	9951.95	40291.14	51675.60	90051.05	71923.71	31450.10	31856.61
Niger	25301.97	17661.14	23633.86	56249.72	54208.45	90613.35	86953.61	64527.65	64752.24
Ogun	91508.85	61092.69	61555.95	58699.83	104693.94	83910.16	201497.62	157840.41	158265.25
Ondo	41799.82	27751.53	27547.09	35335.21	52805.19	74211.53	77227.06	51563.76	51820.07
Osun	8680.24	20961.79	54762.61	42508.15	49277.32	53116.74	118375.52	55242.00	55866.81
Oyo	37371.79	39608.10	38461.56	49647.07	58367.49	73105.06	196522.44	163862.04	164176.29
Plateau	20387.54	33729.50	29188.95	36687.23	50342.86	78774.08	65367.96	59430.72	59491.41
Rivers	454508.10	245283.02	143723.05	237239.22	221773.70	169602.85	178928.31	188191.52	188098.01
Sokoto	4698.55	28570.69	9860.18	37580.00	33844.03	55441.54	62200.36	48929.77	49061.78
Taraba	709.00	5300.14	7723.51	22109.19	38775.38	40342.83	41413.29	31485.09	31584.26
Yobe	2032.45	11485.90	27060.98	26776.39	33766.85	34982.94	57059.50	36172.39	36379.05
Zamfara	3390.40	4561.23	1776.63	34154.93	34903.38	43276.76	29812.26	31562.56	31546.40
Abuja	49312.00	28786.70	55399.48	208291.71	141520.94	353863.25	295076.22	261529.98	261871.11
DEMAND FOR HHK PRODUCT SINCE 2007							*SOURCE NNPC PMI FIGURES*		

Appendix VI: Premium Motor Spirit Supply To State

PREMIUM MOTOR SPIRIT SUPPLY TO STATE								(000.LITRES)	
States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	68754.24	80210.61	127431.78	122939.84	104739.94	141464.60	215227.72	189839.33	260123.36
Adamawa	102431.08	89797.57	146513.32	188662.09	193269.17	215651.01	335528.16	319378.61	431319.91
Akwa-Ibom	52596.44	70537.88	103647.04	108755.09	114771.92	203709.66	236570.97	320939.17	442237.10
Anambra	34872.61	121559.02	109614.11	106978.43	133040.72	165027.20	369496.81	363101.79	462294.10
Bauchi	80161.76	74422.55	115532.43	281264.15	299973.73	278959.37	424167.83	291735.95	333043.60
Bayelsa	10501.85	4565.38	21941.73	54546.13	103108.24	170116.84	101754.91	110893.72	174825.94
Benue	78948.97	89696.89	125451.50	124661.08	152120.60	188403.48	169190.23	136272.30	171494.00
Borno	83350.02	76888.09	131341.43	162084.55	214655.63	197017.57	392151.88	310780.56	458371.38
Cross-Rivers	130665.17	116587.15	190079.78	154556.62	146478.73	207114.66	190687.02	221180.41	259465.65
Delta	236358.01	314876.14	333754.11	290949.58	276431.02	419117.26	483898.63	549104.60	830486.66
Ebonyi	9019.54	18297.28	60139.99	103616.60	36455.99	61503.98	51984.45	65932.76	73893.79
Edo	189389.05	155822.23	240712.69	208036.61	227920.29	277819.00	364486.10	494203.03	287620.93
Ekiti	47162.24	47043.40	78740.70	99247.29	108921.61	138101.48	259959.83	260980.83	404448.96
Enugu	90693.17	124339.21	132361.93	142986.62	129366.00	197750.68	143426.35	92420.01	349793.83
Gombe	44925.17	89830.38	96499.92	109944.51	177652.59	210243.74	212271.64	133502.18	334440.75
Imo	85510.22	84863.15	110494.05	102598.79	137351.24	206666.84	236052.34	228420.88	353426.19
Jigawa	55662.53	86109.11	109363.70	128612.87	126059.92	107174.06	180276.34	106413.76	148165.74
Kaduna	232720.28	277204.75	422749.91	474099.52	622681.33	678961.05	577112.99	421490.46	1146027.04
Kano	291248.38	306350.47	526478.30	417487.96	554337.54	407732.94	627498.18	530657.59	733874.38
Katsina	72029.53	111322.88	164228.11	343941.86	320326.11	296295.29	462649.19	240229.64	396319.02
Kebbi	42339.29	51067.24	142262.21	140519.99	252397.87	228176.82	431943.93	240687.45	365982.89
Kogi	63458.83	200013.16	272538.94	273008.84	185473.95	269850.94	218029.31	148169.86	335497.70
Kwara	169129.62	108030.02	150397.58	149292.30	159123.85	134927.02	326499.59	249771.36	410115.38
Lagos	2567652.85	1640174.29	2118107.66	1928735.31	1041644.53	529158.00	2500803.75	2359315.64	3758632.80
Nasarawa	138700.11	111903.90	99954.57	149467.69	239401.88	328431.81	309692.36	108474.52	593249.78
Niger	284398.31	506260.10	398798.86	392241.04	257462.16	228529.55	374408.77	285287.59	351539.29
Ogun	522578.85	300537.18	422486.48	424380.76	230254.90	249894.96	867617.52	731483.04	303254.70
Ondo	193759.89	142846.59	158164.62	236465.39	223721.29	230907.39	332527.76	235550.04	357353.38
Osun	140993.09	107923.80	182818.35	302655.92	157924.14	162433.29	509706.62	228210.75	329703.58
Oyo	492754.20	395082.41	497517.64	561741.64	339418.32	197044.76	846195.18	750794.18	827356.20
Plateau	111601.29	153687.08	186327.80	164250.73	193963.79	244006.17	281464.30	258312.17	374092.54
Rivers	457891.03	501746.02	545523.62	518788.50	449201.10	553169.99	770437.55	721694.27	1043108.32
Sokoto	41412.70	99653.08	112539.83	113626.37	156774.36	183942.01	267825.13	211680.61	315689.28
Taraba	27463.68	57083.77	69805.05	61136.97	101370.24	120961.16	178319.20	118040.52	186081.43
Yobe	76051.64	130577.00	170868.35	135765.70	177472.47	115961.83	245689.38	124838.24	200796.23
Zamfara	40977.61	84377.65	109091.55	141542.21	158513.27	136544.06	128366.98	136740.01	204359.43
Abuja	759900.56	473237.38	892716.31	1095880.46	1042740.57	1189733.52	1270552.46	1327866.46	1949177.76
PREMIUM MOTOR SPIRIT SUPPLY TO STATE SINCE 2007								*SOURCE NNPC PMI FIGURES*	

Appendix VII: Automated Gas Oil (AGO) Supply To States

Appendix VIII: House Hold Kerosene (HHK) Supply To States

AUTOMATED GAS OIL (AGO) TO STATE *(000.LITRES)*

States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	85498.18	44791.91	40859.57	40565.65	53743.06	61066.96	63723.45	70393.93	108617.92
Adamawa	54141.89	18257.55	20460.49	61508.38	74671.95	89247.45	99341.35	102748.51	182616.91
Akwa-Ibom	35985.45	21567.34	13247.78	36429.81	54500.57	85579.39	70043.64	98525.56	137382.49
Anambra	17625.15	27900.11	16551.70	58611.01	72623.58	67349.13	109398.60	77527.48	85912.98
Bauchi	46310.08	17152.55	14001.15	73019.87	99870.41	114176.93	125585.30	131449.23	148686.17
Bayelsa	5360.82	1308.02	3238.06	72068.50	60041.18	71439.47	30127.04	82246.59	166918.61
Benue	16988.00	468525.09	14339.65	46889.41	72116.55	70492.24	50092.82	81156.07	125398.57
Borno	9714.51	9370.77	104986.65	65311.79	77684.45	79886.84	116106.19	91971.85	133392.75
Cross-Rivers	87763.66	23807.94	20149.79	87846.43	86544.58	83342.31	56457.57	95950.05	99237.86
Delta	27318.34	468802.08	523748.94	524373.75	326349.97	190033.11	143270.07	218780.68	297001.91
Ebonyi	4415.30	14076.13	13529.69	26617.35	43204.96	30043.02	15391.27	34586.68	91507.45
Edo	59047.49	177210.27	121300.93	254045.13	236860.83	114139.76	107915.06	131406.44	137520.02
Ekiti	3113.92	9917.21	36476.85	40754.91	59552.23	59372.33	76967.49	68353.98	86090.22
Enugu	67634.16	35186.01	48191.28	55017.95	60670.12	82187.56	42464.89	94620.61	149307.09
Gombe	29653.83	18140.92	21946.14	54685.18	90666.02	90099.28	62848.23	103729.30	127874.75
Imo	95433.31	46010.81	18876.25	51614.60	61864.16	83337.60	69889.09	95944.64	143349.94
Jigawa	2665.88	7390.38	20076.01	33477.66	39612.60	46587.65	53375.24	53635.28	94841.62
Kaduna	58512.82	243531.07	85892.85	350296.31	296412.04	286578.05	170868.47	329930.63	215227.36
Kano	118055.74	68978.30	137051.17	162401.96	104311.62	168823.42	185786.24	194362.46	120184.98
Katsina	41989.69	22391.98	29184.53	63398.67	82502.83	111061.41	136978.65	127862.41	74671.73
Kebbi	252099.72	27888.67	23356.89	32159.38	56781.06	89710.41	127887.61	103281.50	128421.83
Kogi	317.48	24668.53	119847.13	71207.31	86726.84	104668.62	64552.93	120502.53	114362.53
Kwara	3766.64	23191.07	38956.33	43704.14	67970.17	60029.64	96668.22	69110.72	75574.69
Lagos	466470.47	322376.24	674217.72	509631.47	365321.56	254087.88	740424.36	292525.45	47665.29
Nasarawa	17491.36	18411.03	15269.75	53933.36	69947.99	119303.57	91693.03	137351.41	111066.17
Niger	30894.95	26850.93	36262.55	75295.39	73376.45	120048.52	110852.91	138209.06	124060.27
Ogun	144286.83	92881.65	94448.24	78575.08	141713.51	111167.85	256879.47	127984.95	136861.13
Ondo	65907.89	43191.76	42266.82	47299.41	71477.00	98318.69	98453.01	113492.01	73867.59
Osun	13686.59	31869.04	84024.89	56901.04	66701.68	70371.38	150911.16	91016.92	111933.72
Oyo	58926.07	60217.77	59013.41	66457.14	79006.12	96852.78	250536.86	111504.34	122903.72
Plateau	32146.12	51280.30	44785.99	49109.21	68144.99	104363.35	93234.42	120151.08	139397.45
Rivers	716646.93	372913.54	220521.14	317566.36	300192.46	224697.27	228106.95	258688.73	278796.35
Sokoto	7408.46	43437.15	15128.94	50304.26	45811.22	73451.38	79296.31	84562.86	65233.43
Taraba	1117.91	8058.01	11850.56	20595.17	52486.28	53447.95	52795.78	61523.27	95034.68
Yobe	3204.67	17462.46	41520.95	35842.65	45706.74	46346.92	72742.37	53358.13	96847.99
Zamfara	5345.83	6934.62	2725.97	45719.50	47245.15	57334.94	38006.20	66008.38	77223.24
Abuja	77752.84	43765.56	85002.07	278817.47	191562.47	468813.51	376178.25	539734.06	315625.87

SUPPLY OF HHK PRODUCT TO STATE SINCE 2007 *SOURCE NNPC PMI FIGURES*

HOUSE HOLD KEROSENE SUPPLY TO STATE *(000.LITRES)*

States	2007	2008	2009	2010	2011	2012	2013	2014	2015
Abia	19653.40	22302.99	12139.36	37784.67	34619.43	26637.20	48982.24	63929.39	57384.51
Adamawa	11130.24	15328.05	10105.20	20679.72	37716.85	30827.75	33848.74	44177.05	39654.35
Akwa-Ibom	10566.82	6994.91	7263.67	23717.10	33257.50	21495.47	12954.71	16959.33	14225.09
Anambra	10984.93	19764.77	6018.33	48137.37	61744.10	40621.30	31043.23	46516.22	36368.30
Bauchi	3522.38	8072.44	1372.37	8268.03	31529.68	16439.90	17360.15	22865.51	20345.09
Bayelsa	6536.75	71197.32	7347.09	20220.96	38908.80	21510.71	29894.15	39016.48	33022.10
Benue	17062.51	9687.11	11928.67	34920.95	53844.17	22824.22	21941.93	28637.61	25705.78
Borno	38182.28	14895.66	11288.13	25301.97	39566.95	33471.89	29971.09	39116.90	35112.24
Cross-Rivers	99857.33	66458.12	100430.50	135956.73	131079.76	139650.81	113749.31	148460.42	133261.52
Delta	13494.27	92489.23	3793.53	14761.00	34451.15	15162?.52	13?787.21	179833.60	161422.81
Ebonyi	43148.37	48399.08	49274.84	79363.31	134282.72	80245.14	62453.22	81513.71	73168.60
Edo	8058.95	289061.82	3010.22	6927.66	25702.84	15892.31	6076.05	7930.19	7118.32
Ekiti	33568.49	28108.73	98079.25	30022.91	41172.81	46310.70	51113.41	66710.50	59880.90
Enugu	10403.33	13393.19	11281.77	38472.37	49416.50	34154.32	27358.31	33706.82	32051.27
Gombe	22717.33	19094.36	18122.97	23620.39	44406.94	46087.66	37676.25	49173.32	44139.12
Imo	12407.60	1240.31	3449.44	10931.59	27728.80	21102.59	19312.18	25205.38	22624.94
Jigawa	31409.32	106580.21	53010.70	184593.76	169480.64	80746.84	57014.98	74413.36	66795.16
Kaduna	39043.24	76705.91	86858.22	114019.36	79528.85	115719.00	104867.28	136868.00	122855.89
Kano	6866.49	3100.80	5653.67	43766.65	93322.36	19391.69	9719.52	12685.48	11386.78
Katsina	3735.88	4381.28	3478.12	25754.06	36928.18	20600.71	24644.71	32165.15	28872.19
Kebbi	2818.51	6730.53	12221.62	15458.01	46744.08	27401.22	18852.35	24605.23	22086.22
Kogi	47217.07	5764.23	8981.63	32162.49	43367.02	20828.62	9404.84	12274.77	11018.11
Kwara	261328.95	175404.25	177140.20	328506.12	234097.26	205139.17	169934.73	221791.08	199084.82
Lagos	15026.48	4319.01	3208.90	21017.13	37210.48	12954.88	20021.17	26130.72	23455.54
Nasarawa	16440.86	8927.08	10350.56	34247.32	43821.23	35409.80	21156.62	27612.65	24785.76
Niger	20271.31	35031.63	52623.57	41792.37	38870.98	55444.70	45149.15	58926.61	52893.89
Ogun	7155.26	10448.68	3697.36	17819.96	36275.24	23692.94	12749.77	18640.42	14936.83
Ondo	10052.22	2939.18	4755.38	22896.81	36096.59	15751.00	13377.09	17459.17	15671.76
Osun	82304.83	32082.64	36103.85	71431.54	67307.80	49886.08	38595.19	47762.37	42872.61
Oyo	71871.29	20619.42	24168.54	33186.63	43325.54	48748.84	38568.43	50337.75	45184.54
Plateau	223877.85	213608.83	207699.33	353314.09	139634.86	257498.23	239632.02	312756.81	280737.77
Rivers	14420.55	21566.21	12925.43	23208.14	23461.23	36788.45	31296.87	40847.25	36665.44
Sokoto	1688.39	3219.18	6926.27	12785.67	18947.62	14596.16	21890.33	28570.26	25645.33
Taraba	2819.36	3919.49	6925.49	23146.67	24628.36	13971.39	12463.93	16267.58	14601.96
Yobe	12676.41	5382.37	3390.28	19702.87	28253.55	18185.41	15394.31	20091.95	18035.00
Zamfara	40933.39	43432.48	30768.58	123597.39	121852.80	58235.38	106617.17	131320.94	117876.73
Abuja	14420.55	21566.21	12925.43	23208.14	23461.23	36788.45	31296.87	40847.25	36665.44

SUPPLY OF HHK PRODUCT TO STATE SINCE 2007 *SOURCE NNPC PMI FIGURES*