YAŞAR UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THE DISTRIBUTION NETWORK MODEL OF PETROLEUM PRODUCT – NIGERIAN DOWNSTREAM SECTOR AS A CASE STUDY

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This study titled “SUPPLY CHAIN DISTRIBUTION OF OIL DOWN STREAM SECTOR (NIGERIA AS A CASE STUDY)” and presented as M.ScThesis by Oyewale LAWAL has been evaluated in compliance with the relevant provisions of Y.U Graduate Education and Training Regulation and Y.U Institute of Science Education and Training Direction and jury members written below have decided for the defense of this thesis and it has been declared by consensus / majority of votes that the candidate has succeeded in thesis defense examination dated……..

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ÖZET

PETROL ÜRÜNÜ İÇİN DAĞITIM AĞ MODELİ - NİJERYA SEKTÖRÜ'NDE VAKA ÇALIŞMASI

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Nijerya hem dünyada hem de Afrika'da büyük petrol üreticileri arasında yer almaktadır. Petrol İhraç Eden Ülkeler Örgütü (OPEC)'nün istatistiklerine ve bu topluluk içerisindeki yerine rağmen, Nijerya'nın sürekli olarak benzin yokluğu çekmesi ve tedarik ağını en iyi şekilde oluşturamaması paradoksal bir durum oluşturmaktadır. Böylece, bu tez ülke ekonomisine katkı sağlamak amacıyla petrol ürünlerinin son kullanıcılara etkin kanallar yoluyla en etkin bir şekilde dağıtımını sağlayacak bir model oluşturarak ülkede yaşanılan yoksunluğu incelemek ve bu konuya katkıda bulunmayı amaçlamaktadır. Böylece, bu çalışmada nihai kullanıcılara kadar olan taşıma maliyetlerini düşürmek için tedarikçi ülkelerden eyaletlerde bulunan son kullanıcılara kadarki ağı analiz etmekteyiz. Modelimizde yağmacılık, yıkıcılık, kötü yönetim, altyapıda yaşanılan sıkıntılar gibi üretim krizlerine ve çatışmalarına neden olan unsurları gözönünde bulundurmayıp, mükemmel durum altında modelimizi geliştirdik.En son olarak, Nijerya petrol endüstrisine ait toplanan veriler ile modelimizi çalıştırdık ve sonuçlar gösterdi ki bazı boru hatları en iyi dağıtım yapısında etkin bir şekilde kullanılmamakta, ama ağın bazı bölgelerinde ortaya çıkabilecek bozulmalara karşı dağıtım ağını destekleyici önemli bir rol üstlenmektedir.

ABSTRACT

THE DISTRIBUTION NETWORK MODEL OF PETROLEUM PRODUCT – NIGERIAN DOWNSTREAM SECTOR AS A CASE STUDY

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Nigeria ranks high among the community of oil producers both in Africa and the world at large. It is, therefore, paradoxical that Nigeria, with such profile in Organization of Petroleum Exporting Countries (OPEC) statistics finds it difficult to optimize its supply distribution spending so much money on transportation and experiencing regular fuel scarcity. This thesis thus reviews the petroleum product supply and distribution systems in the country to ascertain the extent to which the system may have contributed to the present product scarcity in Nigeria thus creating a model to effective distribute the product to the end user at the most effective channel to the interest of the economy of the country. Hence, weanalyzes of the distribution network from the supplying country to the end users in the states to reduce the cost of transportation to the door-step of the end user. In our model, we assume a perfect condition in the petroleum industry irrespective of the production crises and conflicts like pipeline vandalism, communal instability, mismanagement and infrastructural dilapidation. Last, we run our model for the collected data of the Nigerian petroleum industry, and the results show that some of the pipelines are not used efficiently in the optimal distribution, but plays an important role to support the the distribution network in case of any distruptions in some part of the network.

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TEXT OF OATH

I declare and honestly confirm that my study titled “supply chain distribution of oil downstream sector (Nigeria as a case study)”, and presented as Master’s Thesis has been written without applying to any assistance inconsistent with scientific ethics and traditions and all sources I have benefited from are listed in bibliography and I have benefited from these sources by means of making references.

12/6/2013

Oyewale LAWAL

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Nigeria is a natural resource abundant country. In particular, over the past fifty years, the country's oil subsector has grown phenomenally. Both production and exports have increased enormously since commercial production in 1958. For example, crude oil production increased from 395.7 million barrels in 1970 to 776.01 million barrels in 1998. The production increased to 919.3 million barrels in 2006. The Figure however decreased to 777.5million barrels in 2009. In the same way, crude oil exports increased from 139.5 million barrels in 1966 to 807.7 million barrels in 1979(OPEC). The volume of crude oil exports dropped to 390.5 million barrels in 1987 but increased to 675.3 million barrels in 1998. The trend continued for most years after 2000. In the same way, oil revenue increased from 166.6 million Nigerian naira in 1970 to 1, 591,675.00 million Nigerian naira and 6,530,430.00 million Nigerian naira in 2000 and 2008 respectively (Central Bank of Nigeria Statistical Report).

The huge revenues from oil, of course, presented net wealth and thus provided opportunity for increased expenditure and investment; however, the huge revenues complicated macroeconomic management and also made the economy highly oil dependent. In spite of the huge rent from oil, the economy still grapples with rising unemployment and poverty. The dismal performance of the Nigerian economy in the face of huge rents from oil has rekindled interest on the importance of oil in the growth and development process in Nigerian. Hence, the objective of the paper is to examine the effect of minimizing the transportation cost of single product petroleum –Premium Motor Spirit (PMS) relativeto its efficiency in meeting the customer demand using the available transportation network. Specifically, we examine the prospective product availability channels relative to their prices and hence recommend the most reasonable one with the least transportation cost satisfying the demand of the locations considered.

1.2 Scope of the thesis

This thesis is limited to petroleum distribution in Nigeria, the network diagram, parameters and data used in the evaluation are Nigeria sourced, in order to achieving an optimal solution in the distribution of the imported petroleum

product coupled with supply from the local refinery to timely satisfy the demanding population centroid.

1.3History of Nigerian Petroleum Industry

Oil was discovered in Nigeria in 1956 at Oloibiri in the Niger Delta after half a century of exploration. The discovery was made by Shell-BP, at the time the sole concessionaire. Nigeria joined the ranks of oil producers in 1958 when its first oil field came on stream producing 5,100 bpd. After 1960, exploration rights in onshore and offshore areas adjoining the Niger Delta were extended to other foreign companies.

In 1970, the end of the Civil war coincided with the rise in the world oil price, and Nigeria was able to reap instant riches from its oil production. Nigeria joined the Organization of Petroleum Exporting Countries (OPEC) in 1971 and established the Nigerian National Petroleum Company (NNPC) in 1977; a state owned and controlled company which is a major player in both the upstream and downstream.

Following the discovery of crude oil by Shell D'Arcy Petroleum, production began in 1958 from the company's oil field in Oloibiri in the Eastern Niger Delta. By the late sixties and early seventies, Nigeria had attained a production level of over 2 million barrels of crude oil a day. Although production figures dropped in the eighties due to economic slump, 2004 saw a total rejuvenation of oil production to a record level of 2.5 million barrels per day. Petroleum production and export play a dominant role in Nigeria's economy and account for about 90% of her gross earnings. This dominant role has pushed agriculture, the traditional mainstay of the economy, from the early fifties and sixties, to the background.

1.4 Sectors in the Petroleum Industries

The sectors in the Nigeria petroleum industry are mainly classified into upstream Sector and downstream Sector.

1.4.1 Upstream Sector

The upstream sector involves oil exploration, oil production and gas production through the Joint Venture Operations (JVO). The Joint Operating Agreements (JOA) is the basic, standard agreement between the NNPC and the operators. It sets the guidelines and modalities for running the operations. It is different from the Memorandum of Understanding (MOU). While it contains the basic understanding on the joint Venture, the MOU is a response to the specifics of fiscal incentives. One of the partners is designated the operator. The NNPC reserves the right to become an operator. All parties are to share in the cost of operations. Each partner can lift and separately dispose its interest share of production subject to the payment of Petroleum Profit Tax (PPT) and Royalty. The operator is the one to prepare proposals for program of work and budget of expenditure joint on an annual basis, which shall be shared on holdings.

Each party can opt for and carry on sole risk operations. Technical matters are discussed and policy decisions are taken at operating committees where partners are represented on the basis of equity holding.

There are six Joint Venture Operation (JVO) involved in Oil Exploration which are Shell Petroleum Development Company of Nigeria Limited (SPDC), Chevron Nigeria Limited (CNL), Mobil Producing Nigeria Unlimited (MPNU), Nigerian Agip Oil Company Limited (NAOC), Elf Petroleum Nigeria Limited (EPNL) and Texaco Overseas Petroleum Company of Nigeria Unlimited (TOPCON).

1.4.2 Downstream Sector

Downstream Sector involves three refineries, at Kaduna, Port Harcourt and Warri solely controlled by the NNPC having a combined installed capacity of 445,000 barrels per day, a comprehensive network of pipelines and Depots strategically located throughout Nigeria that links these refineries. NNPC, through its subsidiary, the Pipelines and Products Marketing Company (PPMC), supplies only to bulk customers. They, in turn, meet the needs of millions of customers across the country for products ranging from gasoline and jet fuel to diesel, fuel oil and liquefied petroleum gas.

CHAPTER 2: LITERATURE REVIEW

In Nigeria, the 2003 deregulation of the petroleum industry is expected to give room for competition and maximize supply sources in order to enhance price reduction and deflate scarcity. Nigeriapetroleum industry fall out in meeting the countries petroleum demand due to the inability of the available refinery to run at installedcapacities, prompting importation of the finished petroleum. The private investors were also not willing to take over the dilapidated, disrepair and poorly performed state - owned facilities (refineries, depots and pipeline system). Thus, the industry is so plagued by, not only, low utilization of the refineries, but also inadequate distribution (pipeline, rail and road) networks and storage facilities, increased treasury loss to and poor maintenance of facilities and infrastructure by government, products diversion and adulteration, black-marketing, sabotage by oil cartels, fire incidents, smuggling, as well as inefficient monopolistic approach by the government in controlling the industry. (Oriyoosu, 2007:113-115). Alsoemphasized is the low level of maintenance, investment and non-cost recovery in all the downstream chain (Kupolokun, 2007).

The result widespread petroleum products shortage and unending price hikes are the daily reports bringing untold hardship to the rapid growing Nigerian population. Hence, the low petroleum products from local refineries, inadequacy of the product importation at international prices, and particularly, inefficiency of domestic prices of petroleum product set by the government, stand out as the fore setbacks on the downstream. They are not only affect government treasury via lower prices in relation to international prices and the lump-sum subsidy cost of 420billion naira(Nigerian currency) annually, but it also result to low profit margins to the private investors, hence, causing the widespread shortage. The consequent erratic supply of petroleum product subsequently fuel up systemic failure of the sector by setting the stage for negative outcomes of the markets such as price discrimination, black-marketing, diversion, sabotage, adulteration, smuggling of petroleum product and the ultimate higher prices, hence, a vicious cycle. Nigeria aspires, via the downstream sector, to ensure domestic self-sufficiency as well as efficient supply and distribution system. More compelling is the fact that, in the last decades the nation had continuously witnessed the trauma of petroleum product scarcity and higher prices. Equally, compelling is the need

to develop the gas sector which has the potential of doubling the nation's revenue and to come up with alternative(s) to oil. What is the relationship among petroleum products prices, imports, locally refined, sales and domestic demand and distribution in Nigeria? What is the impact of the supply modes and appropriate pricing on petroleum products distribution in the Nigerian economy? The main objective of this study is to provide an assessment of the supply of petroleum products distributionin Nigeria with Premium motor spirit (PMS) as a case study, with emphasis on the short and long run effects of petroleum product prices, imports, local refineries output and effective distribution of the petroleum product. Therefore, this study will contribute to the issue here-in by, not only providing an expository analysis of the inherentinconsistencies in the downstream sector resulting to the non-sustainability of deregulation policy, but also provide a knowledge-based policy formulation and implementation framework to even-out petroleum product scarcity and higher prices through the most optimal distribution cost via available transportation network.

Alternatively, additional pipeline network could be introduced to the network to appreciable and effective aid the product distribution at relatively reasonable cost.

CHAPTER 3: METHODOLODY

3.1 Scope Description

This study basically focuses on the distribution of petroleum products in the downstream sector of Nigerian Petroleum industry with Premium Motor Spirit (P.M.S.) prices, imported and locally refined as well as the sales as determining variables through the transportation cost at various nodes of the network. This study is not time based; it is a simple, single product problem which is liable to expansion to multi product and time series problems relative to available data. The data for this study depend mainly on secondary sources gotten from Nigerian National Petroleum Corporation (NNPC) Statistical Report, OPEC Report Statistics, Petroleum Products Price Regulatory Agency (PPPRA) Pricing Template, text books and papers presented on related issue which are fully referenced.

3.2 Network Description

The supply chain distribution of the petroleum industry in Nigeria is represented as a network of nodes (see Figure 3.1). The supplying nodes in the network are the supplying countries and the local refineries. The sea ports serve as transshipment nodes connecting the supplying countries to the depot/pump station nodes. The nodes represent represents supplying countries, seaports, localrefineries, depots/pump stations and states. Supplying countries and local refineries are the supply nodes.There are so many filling stations defined as customers, hence we take the center of mass of each state as the demand node.Seaport and depot/pump station nodes serve as transshipment nodes connecting the supply nodes and demand nodes. The network connects each depot/pump station node to all the states which is not represented on the network diagram for clarification reason.

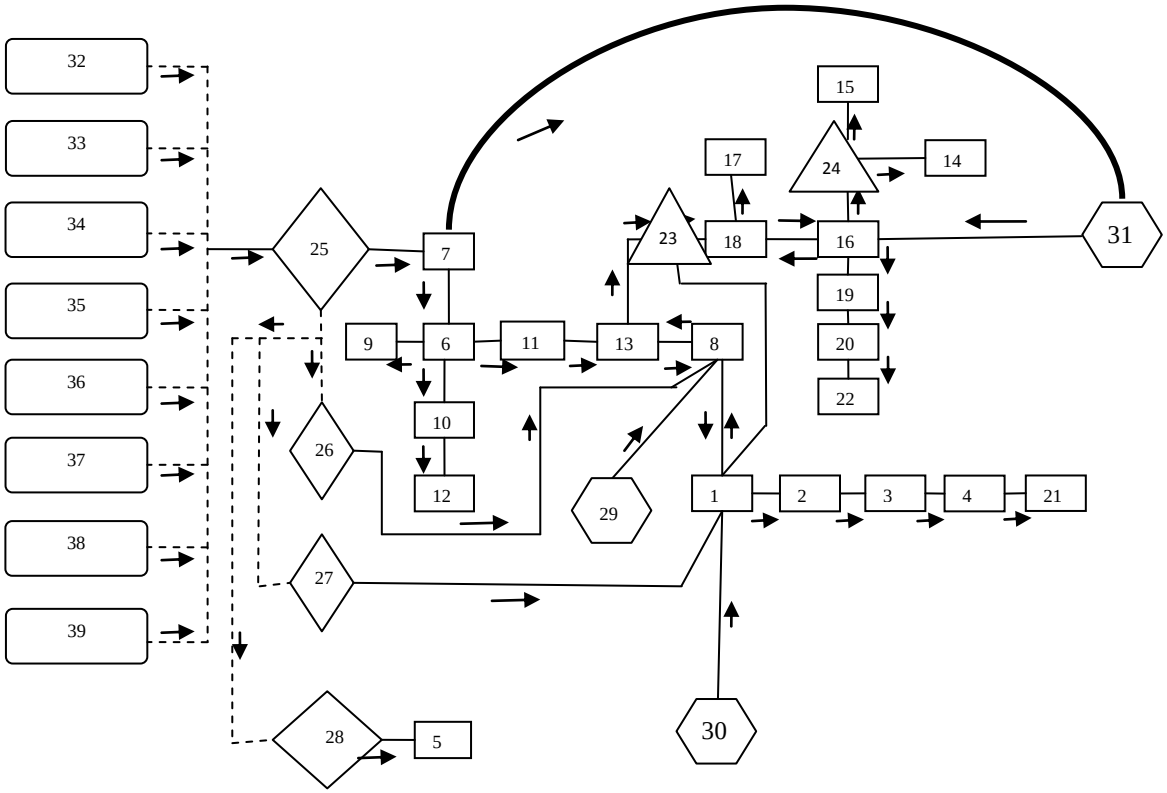

Figure 3.1 Representation of supply chain network of petroleum industry in Nigeria.

InFigure 3.1, Nodes 32 to 38 are the supplying country nodes, nodes 25 to 28 are the seaport nodes, nodes 29 to 31 are the refinery nodes while nodes 1 to 24 are the depot/pump station nodes.The dotted lines represents sea transportation, the single line represents pipeline transportation while the thick line represents trucking transportation. Transportation from the depot/pump station nodes is also by trucking transportation. Table 3.1 and Table 3.2 explains what these nodes represent in Nigeria.

Table 3.1 Depot/pump Station nodes:

Node	Depot	Node	Depot	Node	Depot
1	Port Harcourt	**9**	Ejigbo	**17**	Minna
2	Aba	**10**	Ibadan	**18**	Suleja
3	Enugu	**11**	Ore	**19**	Jos
4	Makurdi	**12**	Ilorin	**20**	Gombe
5	Calabar	**13**	Benin	**21**	Yola
6	Mosimi	**14**	Kano	**22**	Maiduguri
7	Atlascove	**15**	Gusau	**23**	Auchi P/S
8	Warri	**16**	Kaduna	**24**	Suleja P/S

Table 3.2Seaport, Refinery and supplying country nodes:

Node	Seaport	Node	Refinery	Node	Supplying country	Node	Supplying country
25	Lagos	**29**	Warri	**32**	India	**36**	Netherland
26	Delta	**30**	P/Harcort	**33**	France	**37**	Singapore
27	P/Harcourt	**31**	Kaduna	**34**	Italy	**38**	Portugal
28	Calabar			**35**	S/Korea	**39**	Ivory coast

3.3 Data Collection

3.3.1 Supply countries data

Because of issues in production of finished petroleum product in Nigeria, Nigeria purchases finished products from OPEC countries. In Table 3.3, we show the excess capacity in barrels per week of OPEC countries according to their consumption and production . Table 3.3 also shows the distances in nautical miles (Nm) between these countries and Nigeria, as well the transportation cost in U.S dollar per barrel(USD/barrel).When calculating transportation cost between OPEC countries and Lagos Port, Nigeria, we take real transportation cost between

Nigeria and North western Europe (10 USD/per metric ton) as base, then calculate for others considering distances.

Table 3.3Distances between International Supply Countries to Lagos Port

Country	Distance (Nm)	Supply Capacity (B/W)	Transportation Cost (USD/barrel)
India	7,826.5	2,221,212	2.15
France	4,758.0	932,463	1.04
Italy	3,763.0	1,445,206	1.31
S/Korea	10,574.5	752,346	2.90
Nstherland	4,260.5	2,680,545	1.17
Singapore	8,166.0	1,780,667	2.25
Portugal	3,276.0	167,727	1.90
Ivory Coast	457.0	71,001	0.13

Source: U.S. Energy Information Administration, 2011.

3.3.2 Pipeline Data

The pipeline flow cost between the depot nodes is a function of fixed and variable cost with respect to the length of the pipeline,

Pipeline cost = $0.5 + (1.5\ x \frac{Length(km)}{1000})$.

Using this function, we calculated the pipeline cost between each connected pairs of nodes (see Table 3.4). The distance unit was quoted in the source in miles; hence, the data was converted to kilometers for the sake of our model.

3.3.3 Demand Data

The demand of states is the yardstick for the performance efficiency of the model. Hence the state demand becomes a necessary factor in determining the delivery satisfaction to the state centroid.

Table 3.4 Pipeline distances and transportation cost

Pipeline nodes connection	Distance(Km)	Pipeline Cost(USD/barrel)
25-7	9.66	0.51
7-6	117.48	0.67
6-9	46.67	0.57
6-10	280.03	0.91
10-12	271.98	0.90
6-11	152.89	0.72
11-13	109.98	0.66
13-8	90.12	0.63
13-23	106.22	0.66
23-18	521.43	1.27
18-17	80.47	0.62
18-16	164.96	0.74
16-18	164.96	0.74
16-24	103.00	0.65
24-14	259.10	0.88
24-15	263.93	0.89
16-19	265.54	0.89
19-20	1335.75	2.49
20-22	1335.75	2.49
8-1	218.87	0.82
1-8	218.87	0.82
1-2	156.11	0.73
2-3	54.72	0.58
3-4	268.76	0.9
4-21	756.39	1.62
26-13	4.83	0.5
27-1	33.8	0.55
28-5	16.09	0.52
29-13	8.05	0.51
30-1	23.66	0.53
31-16	17.7	0.52
1- 23	328.31	0.99
31-16	9.4	0.51

Source: OPEC Annual Statistics Bulletin 2012

Table 3.5 State demand of premium motor spirit (PMS).

No	**State**	**PMS(B/W)**
1	Abuja	50,910
2	Abia	3,850
3	Adamawa	22,950
4	Akwa Ibom	3,900
5	Anambra	10,350
6	Bauchi	25,450
7	Bayelsa	4,240
8	Benue	5,690
9	Borno	7,080
10	Cross River	7,240
11	Delta	18,170
12	Ebonyi	2,220
13	Edo	12,230
14	Ekiti	4,310
15	Enugu	6,630
16	Gombe	7,390
17	Imo	4,720
18	Jigawa	5,260
19	Kaduna	29,930
20	Kano	26,020
21	Katsina	8,210
22	Kebbi	7,290
23	Kogi	12,360
24	Kwara	7,170
25	Lagos	52,080
26	Nasarawa	9,730
27	Niger	17,080
28	Ogun	15,620
29	Ondo	10,980
30	Osun	8,490
31	Oyo	23,630
32	Plateau	6,540
33	Rivers	19,840
34	Sokoto	6,030
35	Taraba	5,280
36	Yobe	7,850
37	Zamfara	8,010
	TOTAL	484,760

Source: NNPC Annual Statistics Bulletin 2010

3.4 Model Formulation

3.4.1 Model Assumptions

There are several assumptions that accompany the model. The model is assumed to be multiple sourcing, that is, a particular demand node is met by the best optimally possible supply node(s).The model assumes that the transportation cost on a given route is directly proportional to the distance between supply node and demand node. The depot/pump station node is assumed to have an infinity capacity pending the outcome of the solution of the model. The model also assumes no network breakdown, no pipeline vandalism and no change in price and cost. It's a single period model; hence the working period in the model is one week.

All nodes are represented in a set where for every node i, depots/pump stations are 1 to p, and p+1 to m are the refinery nodes, seaport nodes and supply country nodes, while for every node j,depots/pump stations are 1 to q, and q+1 to n are the refinery nodes, seaport nodes and supply country nodes.

$i = 1, 2...p, (p+1)...m;$

$j = 1, 2... q, (q+1)...n;$

$k = 1, 2...a$ state population centroid.

$m = 1, 2 ...b$ vessel.

$r = 1, 2, 3$ vessel routes: for connections (25-26), (25-27) and (25-28)respectively.

The model variables are as follows:

C_{ij} = unit cost of transporting of product from node i to node j;

This include the transportation (shipping) cost from supply countries, pipeline cost within depot connections and trucking cost to node.

P_{ik}= unit cost of trucking of product from node i to state k

This is the trucking cost from the depot/pump station nodes to the corresponding states.

D_k =state demand of the product.

V_m= capacity of each vessel m.

T_r = cycle time for each available vessels on this routes.

S_c =capacity of the supply nodes.

w= working period;

M_{ij}=network Matrix of product flow from node i to node j;

X_{ij}= quantity of product transported from point i to point j

Y_{ik}= quantity of product transported from point i to k

Y_{mr}= number of trips that each vessel m make through route *r*

In formulating the model, the objective (Z) is to minimize total cost of transportation of PMS from supplying country and local refineries through depots involving pipeline network to the states. The quantity of product that's transported from node i to j and vice versa where applicable and the quantity of product transported from node i to state k.

The unit transportation cost (C_{ij}) for each node connection is obtained as

$$\left(C_{ij} = f\left(X_{ij}\right)d_{ij}\right)$$

Where f = cost factor for transporting each barrel of PMS per location distance between nodes. For all locations, (f> 0). The parameter,

dij =pipeline distance between nodes.

Likewise,

$$(C_{ik} = f(X_{ik})d_{ik})$$

Where f = cost factor for transporting each barrel of PMS per location distance from node to state. For all locations, (f> 0). The parameter,

dik =trucking distance from node to state.

$$Z = \sum_{i=1}^{m}\sum_{j=1,i\neq j}^{n} X_{ij}\cdot M_{ij}\cdot C_{ij} + \sum_{i=1}^{p}\sum_{k=1}^{a} Y_{ik}\cdot P_{ik} \qquad (1)$$

Equation (1) is the objective function which expresses the goal of the problem. Minimization of the additional cost of transportation from one node to the other connected in the network diagram plus the transportation (trucking) cost from node 1 to 24 to the 37 states.

$$\sum_{j=1,i\neq j}^{q} X_{ij}\cdot M_{ij} + \sum_{k=1}^{a} Y_{ik} - \sum_{j=1 i\neq j}^{q} X_{ji}\cdot M_{ji} \leq 0 \quad ;\forall i = 1 \ldots p \qquad (2)$$

Equation (2) is the demandconstraint, for i and j = 1 to 24 which supplies the state population centroid (k= 1 to 37); node input minus node output is equal to the amount of product supplied to the corresponding state centroid (k).

Supply nodes (nodes 25 to 39)

$$\sum_{j=q+1,i\neq j}^{n} X_{ij} \cdot M_{ij} - \sum_{j=q+1,i\neq j}^{n} X_{ji} \cdot M_{ji} \leq S_c \quad ; \quad \forall i = (p+1) \dots m \qquad (3)$$

Equation (3) is the supply constraint for i and j =25 to 39, summation of input minus summation of output is less than the supply capacities Sc.

$$\sum_{i=1}^{p} Y_{ik} \leq D_k \qquad \forall k = 1,2 \dots a \qquad (4)$$

Equation (4) is the state demand constraint, for all k = 1, 2 to a, summation of products sent from nodes i = 1 to k is greater or equals to the state demand Dk.

Vessel constraint

$$\sum_{r=1}^{3} Y_{mr} \cdot T_r = w \qquad \forall m = 1,2 \dots b \qquad (5)$$

Equation (5) is the vessel constraint, since we have a working period of 7 days, all vessels have the potential of running on each route at a stipulated period, relative to the travel time (to and fro) each routes. Hence, the total number of trip each vessel (m) make through route r multiply by the cycle time for route is equal to 7. Therefore,

$$\left[X_{25,26}\right] \leq \sum_{m=1}^{b} Y_{m1} \cdot V_m$$

$$\left[X_{25,27}\right] \leq \sum_{m=1}^{b} Y_{m2} \cdot V_m$$

$$\left[X_{25,28}\right] \leq \sum_{m=1}^{b} Y_{m3} \cdot V_m$$

Product sent between nodes [25-26], [25-27] and [25-28] are less than or equal to summation of number of vessel capacities (V_m) for m=1 to 17 multiply by the number of trips that vessel m makes through route r = 1, 2 and 3 respectively.

$$X_{ij}, X_{ji}, Y_{ik}, Y_{mr} \geq 0 \qquad (6)$$

Equation (6) is the non-negativity constraints where all possible decision variables are equal or greater than 0.

CHAPTER 4: RESULT AND DISCUSSION

4.1. RESULTS

The result of this study emphasizes two important factors in the distribution of PMS in the downstream of the Nigerianpetroleum industry to the target customers.

1. The demand of the target customer.
2. The most economical distribution channel considering the transportation costs relative to their distances to achieve considerably cheapest transportation network.

As shown in the solution network above, from the importing countries supply node, it is most economical to purchase the product from France, Portugal and Ivory Coast out of the whole eight potential suppliers to compliment the locally refined PMS to satisfy the overall customer demand.

Atlas cove Depot supplies Mosimi depot as connected which in turns supplies Ibadan and Ilorin, but does not supply Ejigbo, Ore, and Benin depots as connect. Benin depot otherwise gets its product from Warri refinery and the supply from Delta sea port to satisfy his environ demands.

The network solution did not create any connection between Warri depot (node 8) and Port Harcourt depot (node 1) as no product is transported to and fro these depots as indicated in the connection. Port Harcourt depot got its products from the Port Harcourt refinery and Port Harcourt sea port to satisfy its attaching depots (nodes 2, 3, 4, and 21).

Kaduna refinery fed Kaduna depot which in turn serve its attaching nodes as seen at the upper right hand of the network. The solution also did not recommend the supply from Lagos to Kaduna refinery considering the high transportation factor. Furthermore, as connected Calabar depot (node 5) is served by Calabar seaport. Since we assume an infinity depot/pump station capacity, hence, from the result; an approximate depot/pump station capacity was suggested by evaluating the node accumulation for recommendations to Nigerian depot managers.

Depot nodes with its capacity equal to 0 is referred to as transshipment nodes as in case of Aba depot (node 2).Table 4.1 shows the resultsthat highlights the states served by each depot and the quantity served.

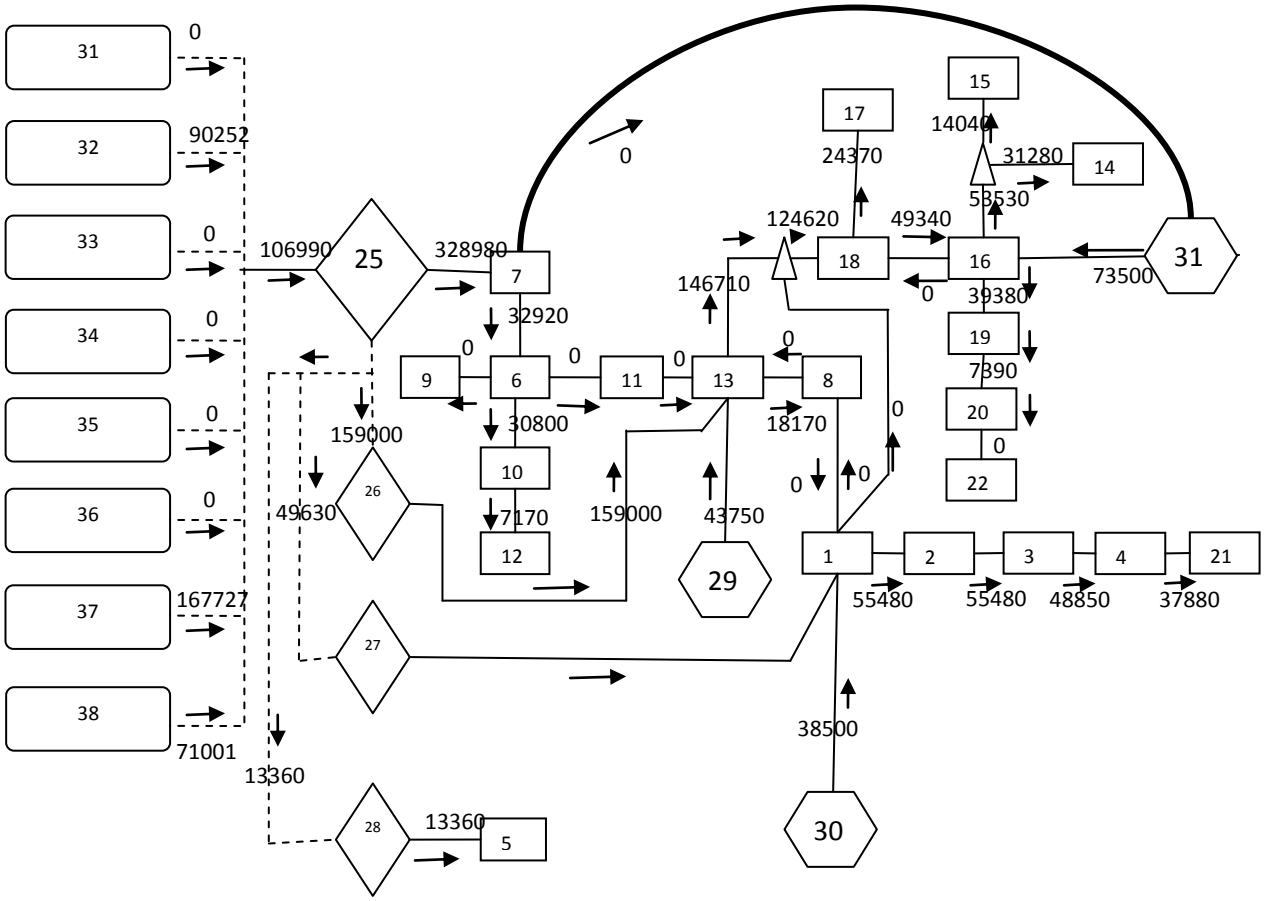

Figure 4.1 Solutionnetwork of the product distribution solved by AMPL Optimization Software.

4.2 DISCUSSION

Deductively, the Total (B/W) column from Table 4.1 is the depot/pump station capacity in barrels per week, considering these values which are a possible capacity of these depots, there is no need for depot expansion nor pipeline expansion as these delivery capacity is attainable in a week as proposed.

Table 4.1 shows the depot that serves each state relative to their distance and transportation cost to satisfy their demand. Hence it was discovered that nodes 9 and 11 which are Ejigbo depot and Ore Depot are dormant, hence resources channeled to their management could be used to develop other dilapidated infrastructures. Likewise pipeline connection between nodes 1 and 8 - Port Harcourt and Warri did not send any product in either direction .

Table 4.1 Result table highlighting proposed depot capacity.

S/N	**Depot node**	**State supplied**	**Quantity supplied(B/W)**	**Total(B/W)**
1	Port Harcourt	Abia,Bayelsa,Imo,Rivers	3850,4240,4720,19840	32,650
2	Aba	transhipment node	0	0
3	Enugu	Enugu	6630	6630
4	Makurdi	Benue,Taraba	5690,5280	10,970
5	Calabar	Cross river,Akwa ibom,Ebonyi	7240,3900,2220	13360
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	67700
8	Warri	Delta	18170	18170
9	Ejigbo	No Product	0	0
10	Ibadan	Oyo	23630	23630
11	Ore	N/A	0	0
12	Ilorin	Kwara	7174	7174
13	Benin	Anambra,Edo,Ekiti,Ondo	10350,12230,4310,10980	37870
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Kaduna	29930	29930
17	Minna	Kebbi,Niger	7290,1708	8998
18	Suleja	Abuja	50910	50910
19	Jos	Bauchi,Plateau	25450,6540	31990
20	Gombe	Gombe	7390	7390
21	Yola	Adamawa,Borno,Yobe	22950,7080,7850	37880
22	Maiduguri	N/A	0	0
23	Auchi	Kogi,Nasarawa	12360,9730	13333
24	Zaria	Katsina	8210	8210

Table 4.2 Depot/Pump Station Nodes and their recipient State

State	**Node**	**Depot/Pump station**
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	13	Benin
Bauchi	19	Jos
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	20	Gombe
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	16	Kaduna
Kano	14	Kano
Katsina	24	Zaria
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	17	Minna
Ogun	7	Atlas Cove
Ondo	13	Benin
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	19	Jos
Rivers	1	Port harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

4.3 SCENARIO ANALYSIS

After obtaining the network solution, different breakages scenario in the pipeline network were considered as shown in Table 4.3

Table 4.3 Case Scenario Table

Cases	Breakage Scenario	Total Cost	% Cost Increment
Original Case	No Breakage	1,726,450	0
Case 1	13,23	1,785,850	3.4
Case 2	16,18/18,16	1,779,690	3.1
Case 3	27,1	1,767,430	2.4
Case 4	16,19	1,774,580	2.8
Case 5	29,13	1,773,700	2.7
Case 6	25,26	1,784,200	3.3

In Case 1, we assume that there is a breakage in the reversible-flow pipeline connection between node 16 and node 18 –Kaduna depot and Suleja depot.It is observed that depots 19, 20 and 22 becomes dormant due to lack of product supply while there initial recipient are served by best alternative depots.The detailed solution can be seen in Table 6.8 and Table 6.9.The solution is represented in Figure 6.1 in the appendix.

Case 3: This scenario occur when there is a breakage in the pipeline connection between node 27 and node 1 –PortHarcourt Seaport and PortHarcourt depot.It is observed that product through other local sea transportation means are increased i.e nodes 26 and 28 to satisfy the recipient of the broken pipeline linkage.The detailed solution can be seen in Table 6.10 and Table 6.11.The network solution is represented in Figure 6.2.

Case 4: This senerio occur when there is a breakage in the pipeline connection between node 16 and node 19 –Kaduna depot and Jos depot.It is observed that the supply chain in the that portion of the network (from nodes 16 to 19 to 20 to 22) remain dormant due to lack of product while the initial recipient are supplied by the best possible alternative.The detailed solution can be seen in Table 6.12 and Table 6.13.The network solution is represented in figure 6.3.

Case 5: This scenario occur when there is a breakage in the pipeline connection between node 29 and node 13 –Warri refinery and Benin depot.Its is observed that flows in the cheapest means of transportationt (local sea transportation) are increased for sufficient flow in the network system to satisfy the initial recipient of the broken pipleline and an increase in the supply of node 33 to compensate for the supply from the broken refinery linkage.The detailed solution can be seen in Table 6.14 and Table 6.15.The network solution is represented in figure 6.4.

Case 6: This scenario occur when there is a breakage in the pipeline connection between node 25 and node 26 –Lagos Seaport and Delta Seaport.It is observed that product flow in the other two local sea port and to node 7 are increased to compensate for the supply deficiency from the broken sea transportation network.The detailed solution can be seen in Table 6.16 and Table 6.17.The network solution is represented in figure 6.5.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Resources saving is an important objective in the industry today, every progressive industry want procure as much saving as possible despite their interest of completing required production which the petroleum industry is not an exemption .Through this model a lot of resources that would be useful in other sector of development could be saved if utilized sighting the fact that only 1,726,450 U.S dollar is required for this product distribution for a period of one week, which would be more exorbitant using any alternative mean.

Furthermore, this model is liable to reasonable manipulation relative to more data availability while it still serve as a saving mechanism to transportation of petroleum product and enhancing prompt delivery as required.

5.2 Recommendation

From this case study, it is advisable to evacuate dormant nodes and pipeline from this network to save enough resources that would be useful in other sector of life in the Nigerian economy, thus saving transportation and distribution cost and reduces or eradicates petrol station long unnecessary queues due to product unavailability. Furthermore, it is recommended that trucking connection (25-31) – trucking from Atlas cove to Kaduna should be an alternation if there is pipeline connection problem like vandalization or leakage, otherwise, it should be abandoned.

6.0 APPENDIX

6.1. INPUT DATA

Table 6.1 Nodes connections, Distances and Costs (*OPEC Annual Statistics Bulletin 2012*)

Pipeline connection	Distance(KM)	Cost(Naira/Liter)	Cost(USD/barrel)
25,7	9,66	0,51	0,51
7,6	117,48	0,68	0,67
6,9	46,67	0,57	0,57
6,10	280,03	0,92	0,91
10,12	271,98	0,91	0,90
6,11	152,89	0,73	0,72
11,13	109,98	0,66	0,66
13,8	90,12	0,64	0,63
13,23	106,22	0,66	0,66
23,18	521,43	1,28	1,27
18,17	80,47	0,62	0,62
18,16	164,96	0,75	0,74
16,18	164,96	0,75	0,74
16,24	103,00	0,65	0,65
24,14	259,10	0,89	0,88
24,15	263,93	0,90	0,89
16,19	265,54	0,90	0,89
19,20	1335,75	2,50	2,49
20,22	1335,75	2,50	2,49
8,1	218,87	0,83	0,82
1,8	218,87	0,83	0,82
1,2	156,11	0,73	0,73
2,3	54,72	0,58	0,58
3,4	268,76	0,90	0,90
4,21	756,39	1,63	1,62
26,13	4,83	0,51	0,50
27,1	33,80	0,55	0,55
28,5	16,09	0,52	0,52
29,13	8,05	0,51	0,51
30,1	23,66	0,54	0,53
31,16	17,70	0,53	0,52
1, 23	328,31	0,99	0,99
31,16	9,4	0,51	0,51

Table 6.2 Transportation Cost from depots to states centroid

	ABUJA	ABIA	ADAMAWA	AKWA IBOM	ANAMBRA	BAUCHI	BAYELSA	BENUE	BORNO	CROSS RIVER	DELTA	EBONYI	EDO
Aba	6,8	0,5	9,4	0,9	2,0	9,2	1,7	4,5	13,0	3,4	2,5	2,0	3,1
PH	7,2	1,2	10,0	1,5	2,3	10,4	1,4	5,1	13,6	4,0	2,2	2,6	3,4
Enugu	4,4	1,6	8,0	2,4	0,9	7,5	3,0	2,8	11,6	2,0	3,2	0,9	2,7
Makurdi	3,1	4,3	6,6	5,1	3,3	4,7	5,7	0,7	10,3	2,5	5,6	2,8	5,1
Calabar	6,9	1,7	9,4	1,2	3,4	9,3	3,4	4,5	13,0	1,6	4,2	2,0	4,7
Warri	6,1	3,0	11,5	3,5	2,5	10,4	1,6	5,9	15,1	5,4	0,3	4,2	1,5
Benin	5,1	3,1	10,9	3,9	1,9	9,4	2,5	5,3	14,5	4,8	1,2	3,6	0,5
Auchi	3,6	3,1	9,6	3,9	2,0	7,9	3,7	3,9	13,5	3,9	2,7	2,8	1,0
Mosimi	7,0	6,7	13,5	7,5	5,5	11,4	6,1	7,7	17,0	8,4	4,8	7,1	4,1
Atlascove	7,9	7,4	14,4	8,2	6,2	12,0	6,8	8,7	17,7	9,1	5,5	7,9	4,8
Satellite	7,9	7,4	14,4	8,2	6,2	12,0	6,8	8,7	17,7	9,1	5,5	7,9	4,8
Ibadan	7,2	7,6	14,6	8,4	6,4	11,0	7,0	8,9	16,6	9,4	5,7	8,1	5,0
Ore	5,5	4,3	12,1	5,1	3,1	9,8	3,7	6,5	15,7	6,0	2,4	4,8	1,7
Ilorin	5,0	6,3	12,4	7,2	5,2	9,4	6,3	6,7	14,4	7,7	5,0	6,6	6,6
Kaduna	2,0	7,8	7,9	8,6	6,3	4,3	8,8	5,3	9,3	7,1	7,8	7,2	6,1
Kano	4,6	10,4	6,8	11,2	8,9	3,6	11,4	7,3	7,4	9,1	10,4	9,9	8,7
Minna	1,7	7,1	9,7	7,9	5,5	6,2	8,0	5,0	11,1	6,8	7,0	6,5	5,3
Suleja	0,6	6,1	8,7	6,9	4,6	5,2	7,1	3,9	10,2	5,7	6,1	5,6	4,4
Zaria	2,9	8,8	7,8	9,6	7,2	4,2	9,7	6,6	8,7	8,4	8,7	8,2	7,0
Gusau	4,9	10,7	9,7	11,5	9,1	6,2	11,6	8,5	10,5	10,3	10,6	10,1	8,9
Jos	2,6	7,6	5,5	8,5	6,7	2,0	9,0	4,1	7,0	5,9	9,0	6,2	7,3
Gombe	5,6	10,2	2,5	11,0	9,7	2,1	12,3	7,2	3,9	8,1	12,1	8,9	10,4
Yola	8,2	9,0	0,2	9,8	9,0	4,9	11,1	6,0	5,0	7,0	11,3	7,7	10,8
Maiduguri	8,8	12,0	4,3	12,7	12,0	4,5	14,0	8,9	0,6	9,9	14,2	10,7	13,7

Table 6.2 Transportation Cost from depots to states centroid (Continue)

	EKITI	ENUGU	GOMBE	IMO	JIGAWA	KADUNA	KANO	KATSINA	KEBBI	KOGI	KWARA	LAGOS
Aba	4,8	2,0	10,9	0,9	12,4	8,4	10,9	11,8	12,0	4,4	7,1	7,4
PH	5,3	2,8	11,5	1,2	12,8	9,1	11,3	11,7	12,6	5,1	7,7	7,2
Enugu	3,5	0,1	9,1	1,7	10,5	6,4	8,9	9,8	10,2	2,7	6,3	7,0
Makurdi	4,6	2,8	6,4	4,4	7,5	5,1	6,7	8,5	10,6	2,8	7,6	8,2
Calabar	6,4	2,9	10,7	2,5	12,1	9,2	11,7	12,6	12,9	5,5	8,7	9,0
Warri	3,2	3,4	12,1	2,4	11,8	7,7	10,2	11,1	10,5	4,1	5,6	5,4
Benin	2,1	2,8	11,1	2,5	10,8	6,7	9,2	10,1	9,4	3,1	4,5	4,3
Auchi	1,7	1,9	9,6	2,5	9,3	5,2	7,7	8,6	9,3	1,6	4,4	5,2
Mosimi	3,1	6,4	13,0	6,1	11,8	7,9	10,2	10,3	8,1	4,9	3,2	0,8
Atlascove	3,8	7,1	13,7	6,9	12,5	8,6	10,9	11,0	8,8	5,9	3,9	0,1
Satellite	3,8	7,1	13,7	6,8	12,4	8,6	10,9	11,0	8,8	5,9	3,9	0,2
Ibadan	3,5	7,3	12,6	7,0	11,4	7,5	9,8	10,0	6,5	5,7	2,9	2,6
Ore	1,7	4,0	11,4	3,7	11,1	6,9	9,6	10,5	8,4	3,4	3,5	2,9
Ilorin	1,6	5,4	10,5	5,8	9,2	6,4	7,7	7,2	5,6	3,5	0,7	3,1
Kaduna	5,7	6,0	5,4	7,7	4,4	0,3	2,8	3,3	6,2	3,7	5,0	8,4
Kano	8,4	8,6	4,3	10,3	1,6	3,8	0,4	1,6	7,0	6,3	7,3	10,7
Minna	3,6	5,3	7,2	6,9	6,3	3,3	4,8	5,2	4,8	2,9	3,3	6,7
Suleja	4,1	4,3	6,2	6,0	5,9	2,2	4,4	4,8	7,0	2,0	4,0	7,4
Zaria	6,7	7,0	5,3	8,6	3,3	2,1	1,7	2,2	5,4	4,6	5,6	9,0
Gusau	7,7	8,9	7,2	10,5	4,5	4,0	3,6	2,2	4,2	6,5	5,7	9,1
Jos	7,0	5,9	3,0	7,7	4,2	1,4	2,8	4,7	8,8	4,9	6,9	10,3
Gombe	10,1	8,9	0,1	11,0	4,4	4,4	4,0	5,8	11,5	8,0	10,0	13,4
Yola	11,0	8,4	2,7	9,8	7,0	7,0	6,6	8,5	14,1	9,5	12,6	14,3
Maiduguri	13,3	11,3	3,4	12,8	4,8	7,6	6,2	8,0	13,3	11,2	13,2	16,6

Table 6.2 Transportation Cost from depots to states centroid (Continue)

	NASARAWA	NIGER	OGUN	ONDO	OSUN	OYO	PLATEAU	RIVERS	SOKOTO	TARABA	YOBE	ZAMFARA
Aba	5,3	9,1	7,3	4,7	5,5	6,4	7,6	0,7	13,4	6,9	11,9	11,8
PH	6,5	9,7	7,4	4,6	5,6	7,3	8,2	0,4	13,8	7,5	12,5	12,2
Enugu	3,5	7,2	6,9	4,3	5,1	6,0	5,8	2,7	11,5	5,5	10,5	9,8
Makurdi	2,9	7,7	8,0	6,7	5,8	6,8	3,1	5,4	10,1	4,1	8,1	8,5
Calabar	6,0	10,0	8,9	6,3	7,1	8,0	7,3	2,4	14,2	6,9	11,8	12,6
Warri	5,8	7,6	5,3	2,7	3,6	4,4	8,9	2,0	12,3	8,9	13,8	11,1
Benin	4,9	6,5	4,2	1,6	2,5	3,3	8,3	3,0	11,2	8,4	12,8	10,1
Auchi	3,4	6,4	5,1	2,4	2,8	3,9	6,4	3,6	10,3	7,1	11,3	8,6
Mosimi	6,7	5,2	0,8	2,0	1,7	1,4	11,3	6,5	9,9	11,0	14,8	8,5
Atlascove	7,6	5,9	0,8	2,7	2,4	2,1	12,0	7,3	10,6	11,9	15,5	9,2
Satellite	7,6	5,9	0,6	2,7	2,4	2,1	12,0	7,2	10,6	11,9	15,5	9,2
Ibadan	7,5	4,8	2,0	2,8	2,2	0,4	10,9	7,4	9,6	12,1	14,4	8,2
Ore	7,9	5,4	3,2	0,3	1,4	3,0	9,5	4,2	10,6	9,6	13,2	8,8
Ilorin	7,2	2,7	3,0	2,7	1,6	2,0	8,8	6,7	7,8	9,9	12,2	6,0
Kaduna	4,2	3,8	8,4	6,8	7,0	7,3	4,4	8,7	5,4	7,6	7,3	3,7
Kano	5,8	5,9	10,6	9,4	9,2	9,6	5,0	11,3	5,2	8,7	5,0	3,5
Minna	4,0	2,3	6,7	4,9	4,4	5,6	5,5	7,9	7,0	8,1	8,9	4,3
Suleja	2,8	4,0	7,4	5,1	5,3	6,3	4,5	7,0	6,9	7,0	8,0	5,3
Zaria	5,0	4,2	9,0	7,8	7,5	7,9	4,5	9,6	4,3	7,7	6,2	2,6
Gusau	7,0	3,4	9,1	8,7	7,6	8,0	6,4	11,5	2,4	9,7	8,0	0,8
Jos	2,5	6,3	10,2	8,0	8,2	9,2	0,5	8,7	6,8	5,2	4,8	5,2
Gombe	5,5	7,9	13,3	11,2	11,3	12,3	3,2	12,0	9,6	4,4	2,8	7,9
Yola	6,8	10,5	14,4	12,2	12,1	14,0	4,3	10,8	12,2	3,2	3,8	10,5
Maiduguri	8,7	11,0	16,6	15,1	14,5	15,5	6,8	13,8	11,6	6,2	1,5	10,0

Table 6.3 Time statistics it takes for Vessels to travel from Lagos ports to local ports

Lagos port to	Travel time(days)	return time(days)	Av. Waiting time(days)	Loading and offloading time(days)	Total time (days)
Delta port	0,7	0,455	1,34	0,66	3,155
PortHarcourt	1,3	0,845	1,34	0,66	4,145
Calabar port	1,6	1,04	1,34	0,66	4,64

The total time is the time it takes vessel m to travel from Lagos port to the local ports in the network. The total time is the accumulation of the travel time, return time which is evaluated at 65% of the travel time due to the zero content of the vessels at the traveling period, waiting times; both at the loading point and at the discharge point, and the loading and offloading times.

Table 6.4 Supply countries distance and cost calculation

SUPPLYING COUNTRIES	DISTANCE (NM)	TRANSPORTATION COST/MT(U.S $)	TRANSPORTATION COST (USD/BARREL)
INDIA	7826.5	18.37	2.15
FRANCE	3790	8.90	1.04
ITALY	4758	11.20	1.31
S/KOREA	10547.5	24.76	2.90
NETHERLAND	4260.5	10.00	1.17
SINGAPORE	8166	19.20	2.25
PORTUGAL	3276	7.70	0.90
IVORY COAST	457	1.10	0.13

Using the conversion rates; 1 Metric ton = 8.53 Barrels, while the transportation cost is 10 Metric ton from North western Europe which Netherland is a member. (Source; Nigerian House of Assembly Ad-hoc committee report on subsidy, 2012)

Table 6.5 Distance from Lagos to Local seaports

	Lagos	Calabar	Delta(Pennington)	Port Harcourt
Lagos	0	391	166	311
Calabar	391	0	226	159
Delta(Pennington)	166	226	0	149
Port Harcourt	311	159	149	0

Table 6.6 Transportation cost from Lagos to local sea ports

	Lagos	Calabar	Delta(Pennington)	Port Harcourt
Lagos	0,00	0,11	0,05	0,09
Calabar	0,11	0,00	0,06	0,04
Delta(Pennington)	0,05	0,06	0,00	0,04
Port Harcourt	0,09	0,04	0,04	0,00

Table 6.7 Available Vessels (Barges) and their Capacity

Vessel Name	Vessel Owner	Capacity(MT)	Capacity (BARREL)
DESIRE I	Runner Marine LTD.	2974	25368,2
DESIRE II	Runner Marine LTD.	4272	36440,2
DERA I	Runner Marine LTD.	3808	32482,2
DERA II	Runner Marine LTD.	2674	22809,2
MARVEL I	Runner Marine LTD.	4746	40483,4
PRAISE I	Runner Marine LTD.	2432	20745
PRAISE II	Runner Marine LTD.	2440	20813,2
MNEMOSYNE	Saje Shipping NIG. LTD.	4393	37472,3
SAJE 460	Saje Shipping NIG. LTD.	8926	76138,8
HERA	Saje Shipping NIG. LTD.	5811	49567,8
KIRIKIRI	Saje Shipping NIG. LTD..	6574	56076,2
DEMETRA	Saje Shipping NIG. LTD.	2191	18689,2
S215	Saje Shipping NIG. LTD.	10379	88532,9
RHEA	Saje Shipping NIG. LTD.	4398	37514,9
HESTIA	Saje Shipping NIG. LTD.	6574	56076,2
ENERGY 7001	Ringardas NIG. LTD.	3186	27176,6
ENERGY 6503	Ringardas NIG. LTD.	2897	24711,4

6.2. Results of Scenario Analysis

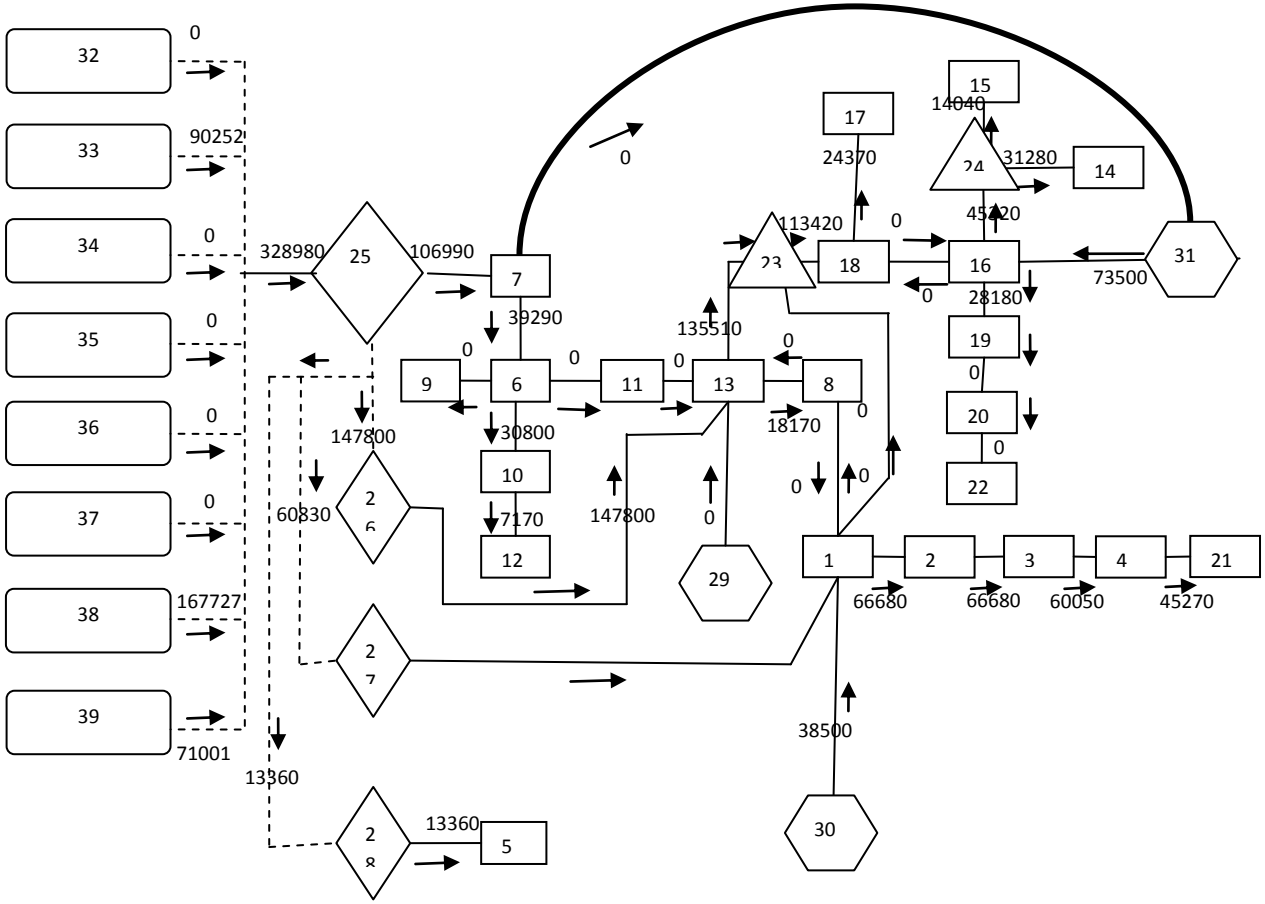

Figure 6.1 : Network solution of Case 1 Scenario

Table 6.8: Case 1 Depot –state Analysis I

S/N	Depot node	State supplied	Quantity supplied(B/W)	Total(B/W)
1	Port Harcourt	Abia,Bayelsa,Imo,Rivers	3850,4240,4720,19840	32,650
2	Aba	transhipment node	0	0
3	Enugu	Enugu	6630	6630
4	Makurdi	Benue,Taraba,Plateau	5690,5280,3810	14,780
5	Calabar	Cross river,Akwa ibom,Ebonyi	7240,3900,2220	13360
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	67700
8	Warri	Delta	18170	18170
9	Ejigbo	No Product	0	0
10	Ibadan	Oyo	23630	23630
11	Ore	N/A	0	0
12	Ilorin	Kwara	7170	7170
13	Benin	Anambra,Edo,Ekiti,Ondo	10350,12230,4310,10980	37870
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Kaduna	0	29930
17	Minna	Kebbi,Niger	7290,17080	24370
18	Suleja	Abuja,Kaduna,Katsina	50910,29930,8210	89050
19	Jos	Bauchi,Plateau	25450,2730	28180
20	Gombe	No Product	0	0
21	Yola	Adamawa,Borno,Yobe	22950,7080,7850,7390	45270
22	Maiduguri	N/A	0	0
23	Auchi	Kogi,Nasarawa	12360,9730	22090
24	Zaria	Katsina	0	0

Table 6.9 Case 1 Depot –state Analysis II

State	**Node**	**Depot/Pump station**
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	13	Benin
Bauchi	19	Jos
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	21	Yola
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	18	Suleja
Kano	14	Kano
Katsina	18	Suleja
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	17	Minna
Ogun	7	Atlas Cove
Ondo	13	Benin
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	4,19	Makurdi,Jos
Rivers	1	Port Harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

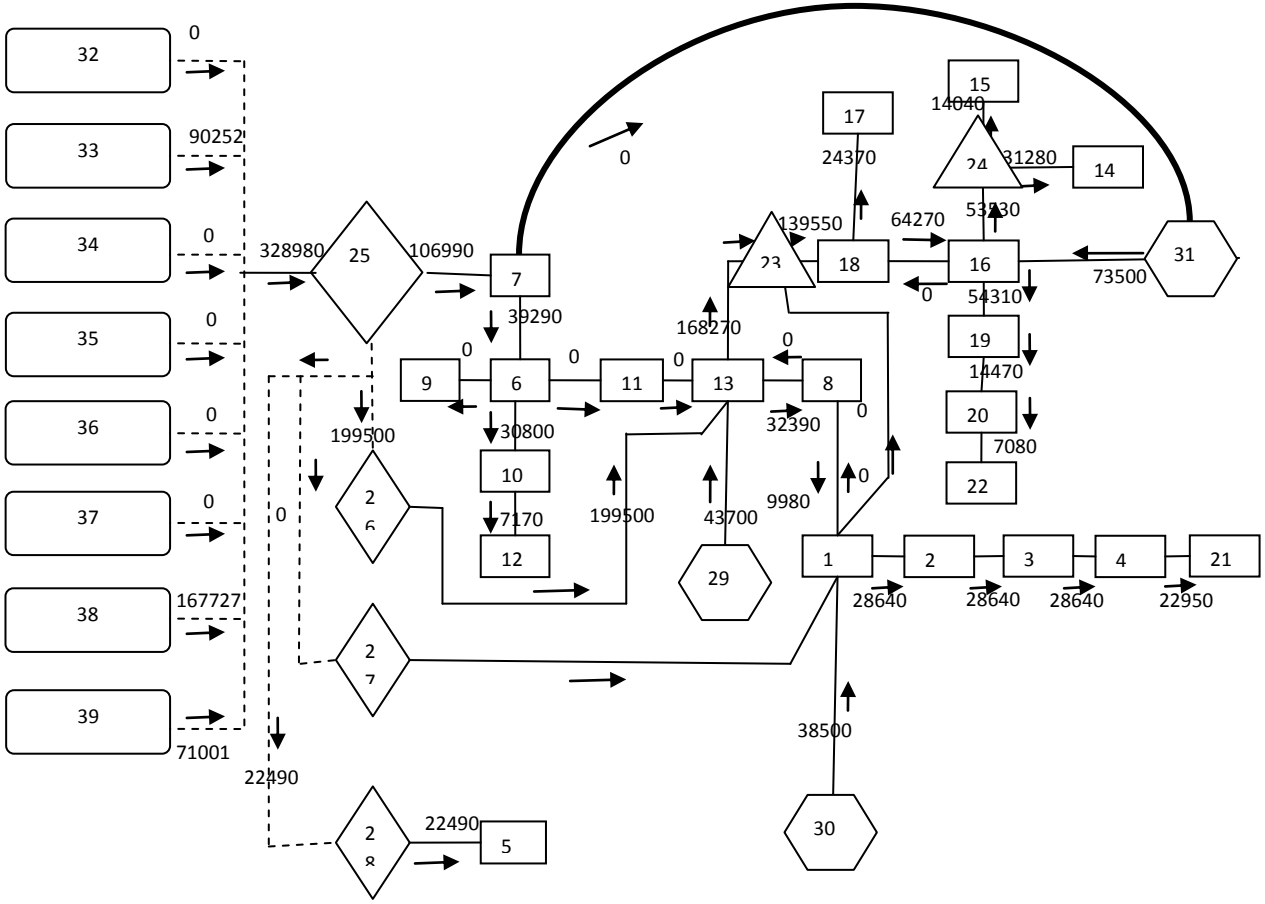

Figure 6.2: Network solution of Case 2 Scenario

Table 6.10 Case 2 Depot –state Analysis I

S/N	Depot node	State supplied	Quantity supplied(B/W)	Total
1	Port Harcourt	Rivers	19840	19840
2	Aba	transhipment node	0	0
3	Enugu	No Product	0	0
4	Makurdi	Benue	5690	5690
5	Calabar	Abia, Akwa ibom, Cross river, Ebonyi,Taraba	3850,3900,7240, 2220,5280	22490
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	53642
8	Warri	Bayelsa	4240	4240
9	Ejigbo	Delta	18170	18170
10	Ibadan	Oyo	23630	23630
11	Ore	N/A	0	0
12	Ilorin	Kwara	7170	7170
13	Benin	Anambra,Edo,Ekiti, Imo,Ondo	10350,12230,4310, 4720,10980	42590
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Kaduna	29930	29930
17	Minna	Kebbi,Niger	7290,17080	24370
18	Suleja	Abuja	50910	50910
19	Jos	Bauchi,Plateau,Yobe	25450,6540,7850	39840
20	Gombe	Gombe	7390	7390
21	Yola	Adamawa	22950	22950
22	Maiduguri	Borno	7080	7080
23	Auchi	Enugu,Kogi,Nasarawa	6630,12360,9730	28720
24	Zaria	Katsina	8210	8210

Table 6.11 Case 2 Depot –state Analysis II

State	Node	Depot/Pump station
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	13	Benin
Bauchi	19	Jos
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	21	Yola
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	16	Kaduna
Kano	14	Kano
Katsina	24	Zaria
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	17	Minna
Ogun	7	Atlas Cove
Ondo	13	Benin
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	4	Makurdi
Rivers	1	Port Harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

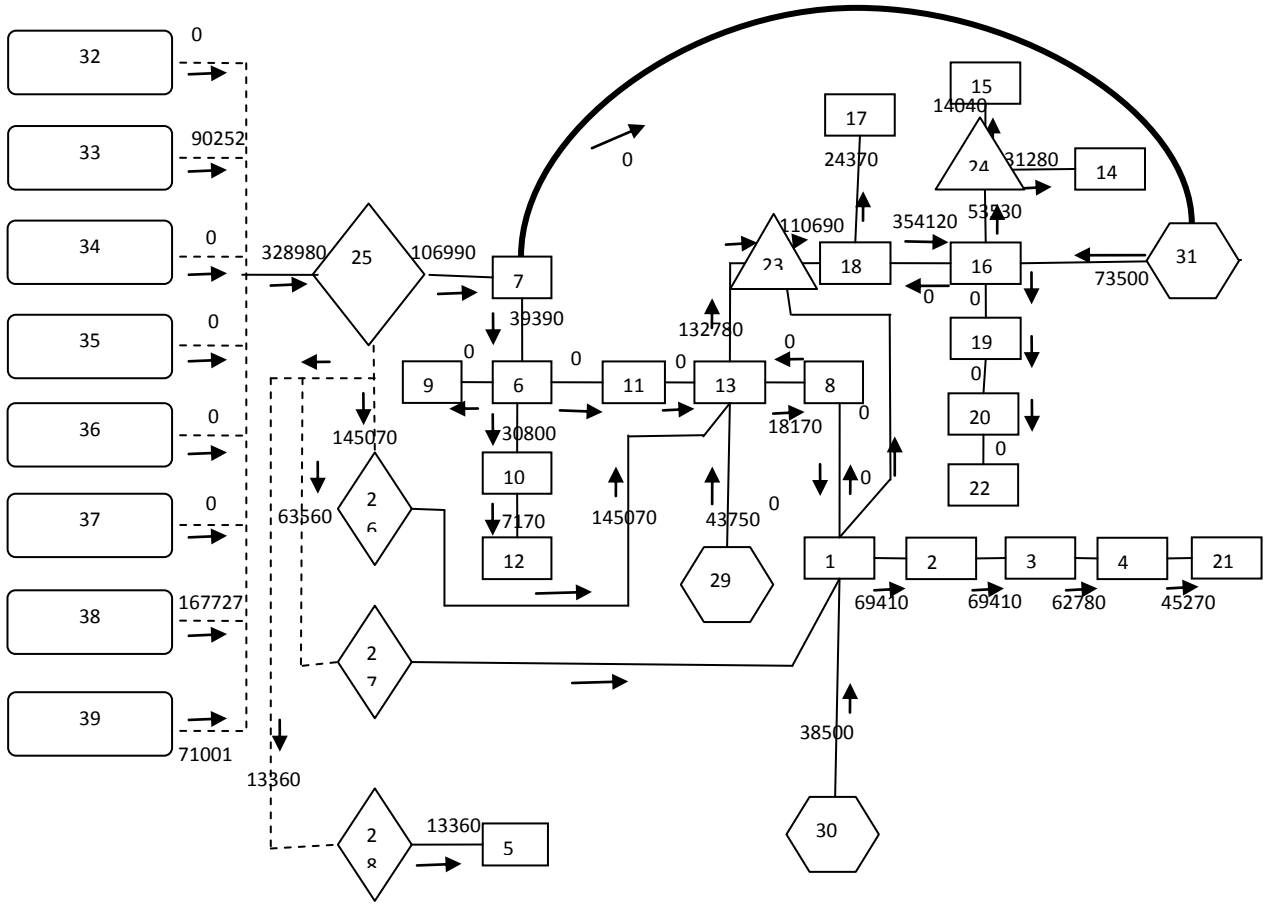

Figure 6.3: Network solution of Case 3 Scenario

Table 6.12 Case 3 Depot –state Analysis I

S/N	Depot node	State supplied	Quantity supplied(B/W)	Total
1	Port Harcourt	Abia,Bayelsa,Imo ,Rivers	3850,4240,4720,19840	32650
2	Aba	transhipment node	0	0
3	Enugu	Enugu	6630	6630
4	Makurdi	Benue,Plateau,Taraba	5690,6540,5280	17510
5	Calabar	Akwa ibom,Cross river, Ebonyi	3900,7240,2220	17210
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	53642
8	Warri	Delta	18170	18170
9	Ejigbo	No Product	0	0
10	Ibadan	Oyo	23630	23630
11	Ore	N/A	0	0
12	Ilorin	Kwara	7170	7170
13	Benin	Anambra,Edo,Ekiti ,Imo,Ondo	10350,12230,4310, 4720,10980	42590
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Bauchi,Kaduna	25450,29930	55380
17	Minna	Kebbi,Niger	7290,17080	24370
18	Suleja	Abuja	50910	50910
19	Jos	No Product	0	0
20	Gombe	No Product	0	0
21	Yola	Adamawa,Borno, Gombe,Yobe	22950,7080,7390, 7850	45270
22	Maiduguri	No Product	0	0
23	Auchi	Kogi,Nasarawa	12360,9730	22090
24	Zaria	Katsina	8210	8210

Table 6.13 Case 3 Depot –state Analysis II

State	Node	Depot/Pump station
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	13	Benin
Bauchi	16	Kaduna
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	21	Yola
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	16	Kaduna
Kano	14	Kano
Katsina	24	Zaria
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	17	Minna
Ogun	7	Atlas Cove
Ondo	13	Benin
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	4	Makurdi
Rivers	1	Port Harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

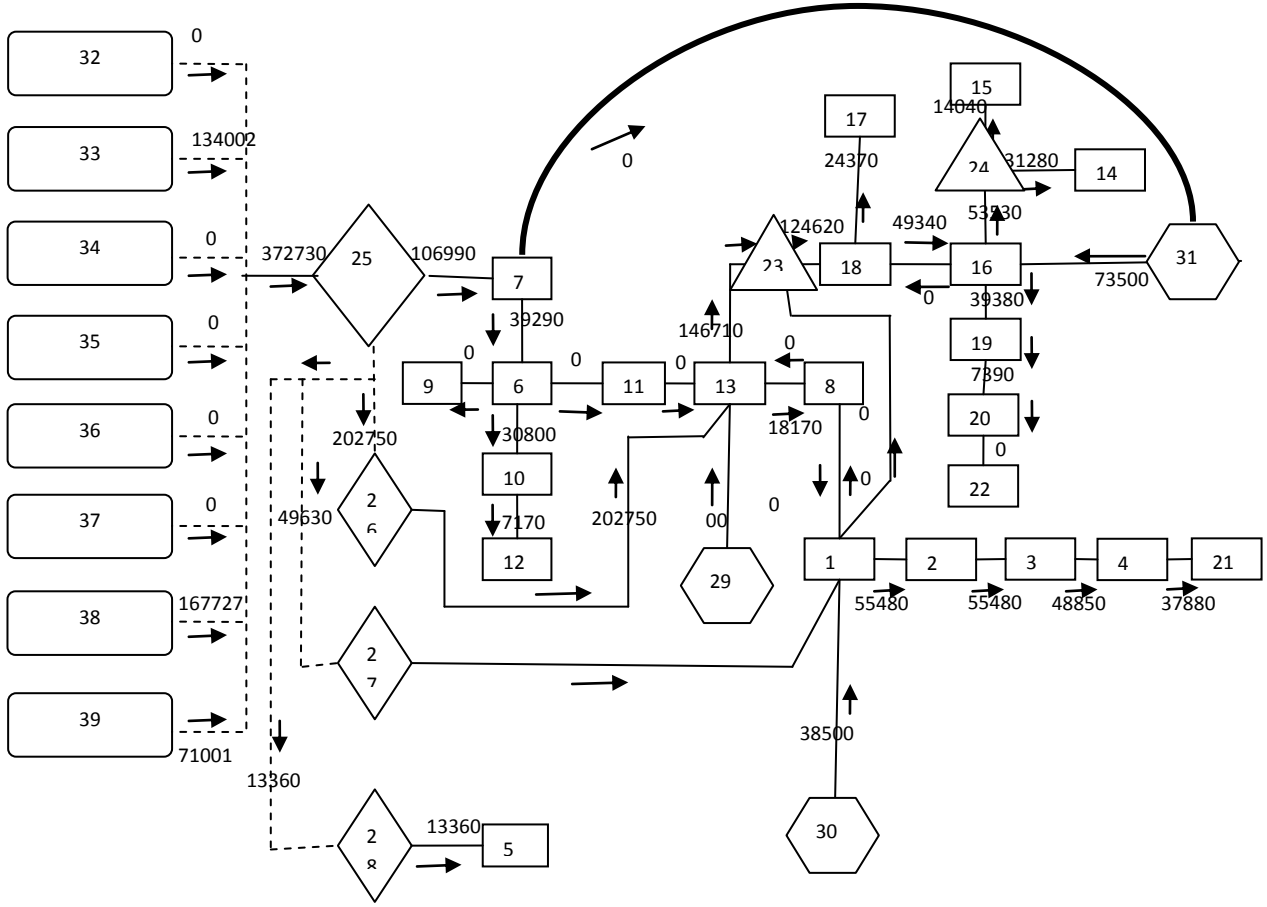

Figure 6.4: Network solution of Case 4 Scenario

Table 6.14 Case 4 Depot –state Analysis I

S/N	Depot node	State supplied	Quantity supplied(B/W)	Total(B/W)
1	Port Harcourt	Abia,Bayelsa,Imo,Rivers	3850,4240,4720, 19840	32650
2	Aba	transhipment node	0	0
3	Enugu	Enugu	6630	6630
4	Makurdi	Benue, Taraba	5690 ,5280	10970
5	Calabar	Akwa ibom,Cross river, Ebonyi	3900,7240,2220	17210
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	53642
8	Warri	Delta	18170	18170
9	Ejigbo	No Product	0	0
10	Ibadan	Oyo	23630	23630
11	Ore	N/A	0	0
12	Ilorin	Kwara	7170	7170
13	Benin	Anambra,Edo,Ekiti,Ondo	10350,12230,4310 ,10980	37870
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Kaduna	29930	29930
17	Minna	Kebbi,Niger	7290,17080	24370
18	Suleja	Abuja	50910	50910
19	Jos	Bauchi,Plateau	25450,6540	31990
20	Gombe	Gombe	7390	7390
21	Yola	Adamawa,Borno,Yobe	22950,7080 ,7850	37880
22	Maiduguri	No Product	0	0
23	Auchi	Kogi,Nasarawa	12360,9730	22090
24	Zaria	Katsina	8210	8210

Table 6.15 Case 4 Depot –state Analysis II

State	Node	Depot/Pump station
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	13	Benin
Bauchi	19	Jos
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	20	Gombe
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	16	Kaduna
Kano	14	Kano
Katsina	24	Zaria
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	17	Ilorin
Ogun	7	Atlas Cove
Ondo	13	Benin
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	19	Jos
Rivers	1	Port Harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

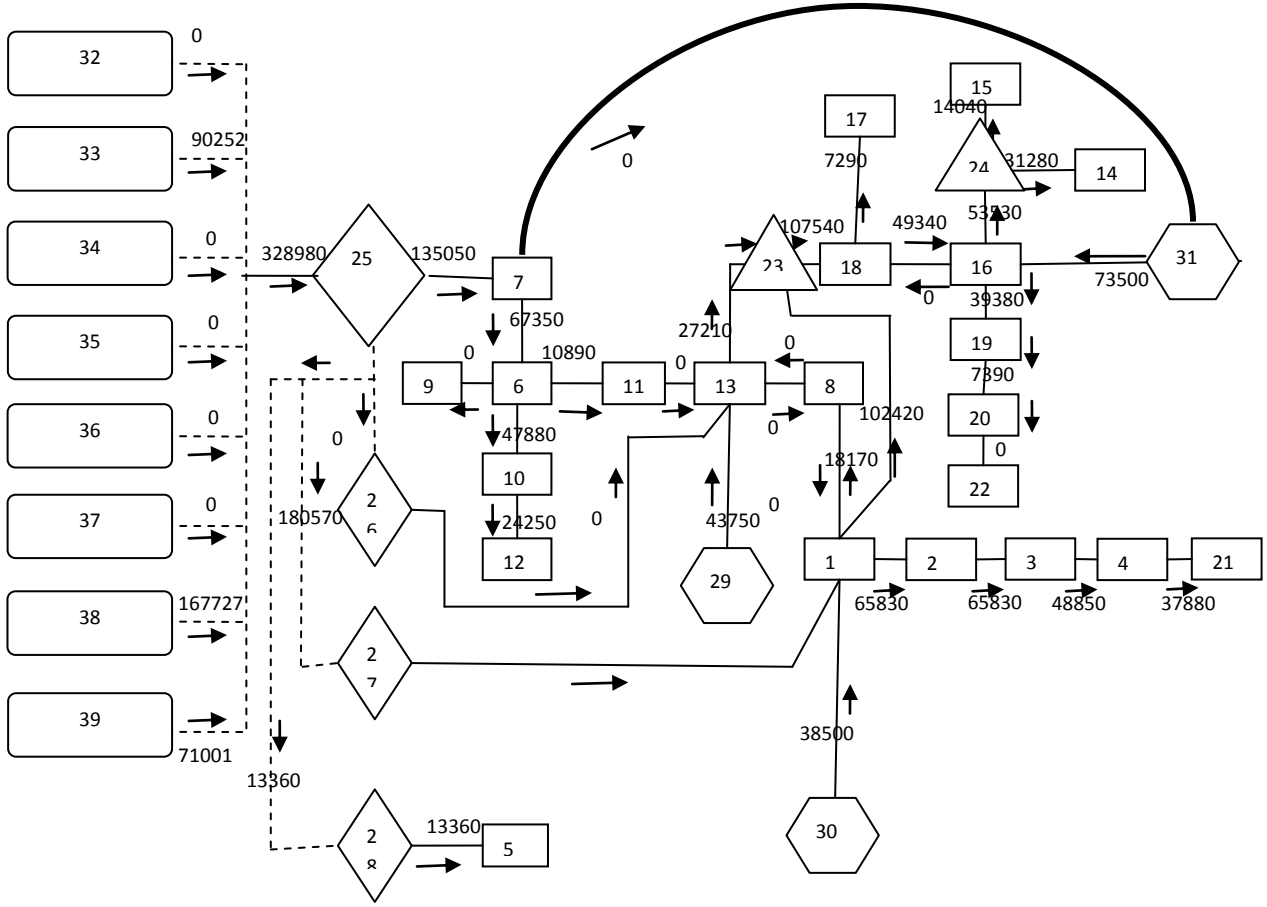

Figure 6.5: Network solution of Case 5 Scenario

Table 6.16: Case 5 Depot –state Analysis

S/N	Depot node	State supplied	Quantity supplied(B/W)	Total(B/W)
1	Port Harcourt	Abia,Bayelsa,Imo,Rivers	3850,4240,4720, 19840	32650
2	Aba	transhipment node	0	0
3	Enugu	Anambra,Enugu	10350,6630	16980
4	Makurdi	Benue, Taraba	5690 ,5280	10970
5	Calabar	Akwa ibom,Cross river, Ebonyi	3900,7240,2220	17210
6	Mosimi	Osun	8490	8490
7	Atlas cove	Lagos,Ogun	52080,15620	53642
8	Warri	Delta	18170	18170
9	Ejigbo	No Product	0	0
10	Ibadan	Oyo	23630	23630
11	Ore	Ondo	10980	10980
12	Ilorin	Kwara,Niger	7170,17080	24250
13	Benin	Edo,Ekiti	12230,4310	16540
14	Kano	Jigawa,Kano	5260,26020	31280
15	Gusau	Sokoto,Zamfara	6030,8010	14040
16	Kaduna	Kaduna	29930	29930
17	Minna	Kebbi	7290	7290
18	Suleja	Abuja	50910	50910
19	Jos	Bauchi,Plateau	25450,6540	31990
20	Gombe	Gombe	7390	7390
21	Yola	Adamawa,Borno,Yobe	22950,7080 ,7850	37880
22	Maiduguri	No Product	0	0
23	Auchi	Kogi,Nasarawa	12360,9730	22090
24	Zaria	Katsina	8210	8210

Table 6.17 : Case 5 Depot –state Analysis II

State	Node	Depot/Pump station
Abuja	18	Suleja
Abia	1	Port Harcourt
Adamawa	21	Yola
Akwa Ibom	5	Calabar
Anambra	3	Enugu
Bauchi	19	Jos
Bayelsa	1	Port Harcourt
Benue	4	Makurdi
Borno	21	Yola
Cross River	5	Calabar
Delta	8	Warri
Ebonyi	5	Calabar
Edo	13	Benin
Ekiti	13	Benin
Enugu	3	Enugu
Gombe	20	Gombe
Imo	1	Port Harcourt
Jigawa	14	Kano
Kaduna	16	Kaduna
Kano	14	Kano
Katsina	24	Zaria
Kebbi	17	Minna
Kogi	23	Auchi
Kwara	12	Ilorin
Lagos	7	Atlas Cove
Nasarawa	23	Auchi
Niger	12	Ilorin
Ogun	7	Atlas Cove
Ondo	11	Ore
Osun	6	Mosimi
Oyo	10	Ibadan
Plateau	19	Jos
Rivers	1	Port Harcourt
Sokoto	15	Gusau
Taraba	4	Makurdi
Yobe	21	Yola
Zamfara	15	Gusau

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