Solving the Fuel Supply and Distribution Problem in Nigeria using a 3-Node Structure Model

By

Onyeizu Chimaeze Chinedu

B.Eng. Petroleum Engineering
Federal University of Technology Owerri, 2002.

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Signature of Author..... Signature redacted .....
Sloan Fellows MBA Program
May 12, 2017

Certified by..... Signature redacted .....
Henry. Birdseye. Weil
Senior Lecturer at Sloan
Thesis Supervisor

Accepted by..... Signature redacted .....
Johanna Hising DiFabio
Director of Sloan Fellows MBA Program

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ABSTRACT

Given that Nigeria is the largest producer of crude oil and natural gas in the world, the country struggles to make liquid fuel available to over 188 million consumers in her domestic market. A review of the key challenges impacting liquid fuel supply and distribution efficiency in Nigeria was performed. Also, measures employed by successive governments were reviewed and key reasons why the problem has been persistent despite investments by governments were highlighted in the study.

However, a disruptive approach – The 3 node structure model to permanently solve the problem of liquid fuel supply and distribution is proposed in this study. Using system dynamics, factors challenging the Nigerian petroleum downstream industry were stated. Current state system dynamic loops with powerful positive and negative feedback effects to the economy of the country were captured and used as the basis for policy recommendations. More so, system dynamics has been used to show the effectiveness of the proposed 3 node structure model as it offers actionable policy frameworks for the Nigerian Government as well as business case for foreign and local investors interested in pursuing an opportunity in the Nigerian petroleum refining industry.

Thesis Supervisor: Henry Birdseye. Weil
Title: Professor of Henry Weil. Birdseye

Dedication

To God Almighty for the gift of strength, sustenance, and life to complete this thesis.

To my wife, Mrs. Chinweoke Joy. Onyeizu for an unequalled support and encouragement during the course of my research

To my sons, Master Onyeizu Jason. Onyeizu (4.9 years), Master Ebubechukwu Jeremy. Onyeizu (3 years), and Master Chidiadi Jaden. Onyeizu (10 months) for giving me hope and inspiration.

Glossary of Terms

NNPC – Nigerian National Petroleum Cooperation

NSM – Node Structure Model

DPDS- Direct Purchase Direct Sale

GDP - Gross Domestic Product

SD – System Dynamics

MCAV- Minimum Crude Allocation Volume

JV – Joint Venture

IOC – International Oil Companies

STBD – Stock Tank Barrels per Day

BBL - Barrels

NDRC- National Development and Reform Commission

CNRC-Conseil National De Recherches du Canada

CNOOC – China National Offshore Oil Corporation

SINOPEC – China Petroleum and Chemical Corporation

API – American Petroleum Institute

IPMAN- Independent Petroleum Marketers Association of Nigeria

PPMC- Pipelines and Products Marketing Company

NRGI-Natural Resource Governance Institute

RPEA-Crude Oil for Refined Products Exchange Agreement

OPA-Offshore Processing Agreement

CBN – Central Bank of Nigeria

D-U - Downstream Upstream Subunit

D-M – Downstream Midstream Subunit

D-D – Downstream Downstream Subunit

PMS – Prime Motor Spirit

Table of Contents

Chapter 1: The Nigerian Petroleum Industry

1.1 Introduction

Nigeria is the largest producer of crude oil in Africa and 10th largest in the world with 37.07 billion barrels of proven oil reserves (WorldAtlas, 2017). In 2015, crude oil production in the country reached a peak rate of 2.7 million barrels per day. For natural gas, Nigeria also has the largest reserve of natural gas in Africa and 7th largest in the world, estimated at 188 trillion cubic feet (The Guardian, 2017).

The oil and gas industry is traditionally divided into 3 major sectors, namely: the upstream sector, the midstream sector, and the downstream sector. The upstream sector comprises of crude oil exploration and production into terminal tanks, the mid-stream sector handles the transportation of produced crude oil to refineries, and the downstream sector covers refining of crude oil into petroleum products, storage, and marketing and distribution of refined products to retailers and consumers. The scope of this study will be limited to the downstream sector but with limited reference to the upstream sector of the industry.

In Nigeria, the structure and governance of operations in the upstream sector is captured in a special Joint-Venture (JV) partnership arrangement between the Nigerian government and the International Oil Companies (IOC's) – the JV agreement sets the guidelines and modalities for the partnership with any foreign company interested in operating in Nigerian Upstream sector. The former is represented in the JV by the Nigerian National Petroleum Corporation (NNPC). In the JV arrangement, NNPC owns between 60% to 70% of the shares while the IOC's retain 40% to 30% (See exhibit 2). This implies that the NNPC or the Nigerian

government is obligated by the terms of the agreement to provide 60% of cash calls for development activities or any capital investments the JV entity decides to pursue. In contrast, the downstream sector is fully managed by the Nigerian Government's NNPC which owns four onshore refineries in different parts of the country. Badmus et al (2012a) stated that NNPC's four downstream refineries have 445,000 stock tank barrels per day (STBD) of total installed processing capacity (See exhibit 4). With a domestic liquid energy demand of about 300,000 STBD, it is feasible for the refineries to supply enough products for domestic consumption and also export the excess for foreign exchange earnings. What is then the cause of persistent scarcity of petroleum products in the country?

Koso and Bello (2013) suggested four reasons for petroleum product scarcity in Nigeria. They include: *Dysfunctional refineries, dependence on imported products, storage and distribution challenges, and heavy regulation in the market system.* Bassey Udo (2000a), Okafor (2000b) added to the list of causes by highlighting: *vandalism of crude oil pipelines[4], hoarding of petroleum products by marketers to manipulate prices, and diversion of allocated products to neighboring countries with land borders.* Additionally, the National Resource Governance Institute (2015), highlighted concerns with the current crude swapping system adopted by the past administration in 2011 when the open account system failed.

In this study, a new structure for the Nigerian downstream industry is proposed that will potentially disrupt the existing system and offer a sustainable path to liquid energy independence and sufficiency in the country. The structure will offer practical solutions to the numerous problems confronting the petroleum downstream

sector in Nigeria. With a population of 186.9 million (Population Pyramid, 2017); demanding for liquid fuel in Nigeria, the new 3-node structure will not only eliminate the challenge of petroleum product refining, supply, and distribution in the country, it will create the critical platform for export of refined petroleum products from the country; thereby growing foreign exchange earnings and the economy. It will create jobs in the sector, eliminate bureaucracy, corruption and other issues identified as the major causes of fuel scarcity in Nigeria.

Chapter 2: Downstream Petroleum Industry Structures

2.1 Variety of structures at country level

Countries adopt different structures in an attempt to effectively and efficiently manage their petroleum downstream sectors. Their ultimate objective has always been to meet domestic demand pressure for liquid fuel and export excess for foreign exchange earnings. Countries like Singapore, USA, and Australia are known globally as dominant players in this industry.

2.2 Centralized and Decentralized Organization of the Downstream Sector

The concept of decentralization or centralization of the petroleum downstream structures of national governments is investigated in this study and the effectiveness and efficiency of both of them are used as a basis for proposing the *3-node structure model* in countries like Nigeria. As stated by Montana & Charnov (1993), a centralized structure restricts authority within the upper levels of an organization. They argue that the advantages of centralizing authority are:

1) The ability to cascade down a shared vision within the organization
2) It allows for speedy execution of programs in the organization, and
3) It could enable efficiency in decision-making since many key stakeholders get to participate in the decision making process.

However, the growing concern with centralization is that the system does not only limit innovation and creativity of subordinate units in an organization. It also creates unnecessary bureaucracy – particularly in situations where only a few group of individuals hold the sole authority to approve projects or decisions. In additionally,

the bureaucratic nature of most centralized systems have only created loop holes for corrupt office holders to divert public funds to private pockets.

On the other hand, a decentralized structure enables major decision making authority to be delegated to lower levels in the organization allowing for continuous ideation, disruptive innovation, unit level efficiency and effectiveness to strive in the organization. Gilikin (2017) in his study of organizational structures discussed the advantages and disadvantages of a divisional organizational structure also known as a Multiunit organizational structure.

2.3 The Multiunit Organizational Structure

Gilikin (2017), defined it as a structure that consists of several parallel teams that focus on single products or services. It is a hybrid of centralized and decentralized structure. This type of structure involves high-level goal setting at the top but with execution authority as well as autonomy on strategy formulation passed on to lower levels of the organization. The response time to pressing energy problems is often delayed as layers of authorities will have to be sort before a strategic decision is made.

For an industry like energy with major strategic relevance to the economic development of a country, it is critical that decision making is brought close to consumers so that demand fluctuations in the market or unplanned upstream downtime events are quickly addressed. Unlike the centralized structure, the multiunit structure tends to move the organization towards a proactive organization rather than a re-active organization. In a multiunit organization (Garvin & Levesque, 2008), annual performance targets and budgets are set at the head office while the

subordinate units' endeavor to meet or exceed the targets. In this case, the subordinate units are financially autonomous and strategies on how to meet their business targets are designed and planned by individual units.

2.4 Downstream Petroleum Industry Structure in China, Australia, and United States

Before 1998, the Chinese energy industry operated a centralized and autocratic style of organizational structure. Although it was not sustainable due to the numerous inherent challenges with centralized structures, oilfields were made to incorporate running cost of hospitals and schools in their operating costs (Meidan, 2016). Thus bloating the marginal cost of crude oil production. At some point, the national oil company could not meet up with growing demand for energy in the country. Pun-Lee Lam (2005) highlighted that in 1998, when, however, the National Development and Reform Commission (NDRC) of China assumed a central management role, China's national oil company was decentralized and re-structured into three major groups – China National Petroleum Corporation (CNPC) and its subsidiary Petro China Company Limited (PetroChina); China Petrochemical Corporation (SINOPEC) and its subsidiaries China petroleum and chemical Corporation; and China National Offshore Oil Corporation (CNOOC) and its subsidiary CNOOC limited. The re-structuring limited the government's authority to drafting of business and strategy plans for the newly established subordinate units. The subordinate units were allowed to independently work out lower level plans and strategies on how to achieve or exceed their silo targets. Additionally, they became

financially autonomous which enabled them to only function as business units under the SINOPEC central organization.

In Australia and United States, a more liberal multiunit arrangement is obtainable. The main difference between downstream and upstream structure in both countries and China is that private sector companies are dominant and autonomous in decision making. The Australian government for example formed the Australian Petroleum Institute (API) to encourage effective collaboration between major stakeholders in the sector. The organization helps the government formulate policies that effectively represent shared interest of the private sector and the government. According to API (2013), the institute's mission is to:

> *"promote and assist in the development of a strong, internationally competitive Australian petroleum products industry, operating efficiently, economically and safely, and in harmony with environment and community standards"*

In Australia, refineries operate based on a standard import parity framework. API ensured that the companies do not enjoy any tariff protection and as a result, profitability is based on product prices across Asia.

Chapter 3: Nigerian Downstream Petroleum Industry Structure – Current State

3.1 Governance

The Nigerian petroleum industry structure is comprised of an active upstream and downstream sector. The governance of the upstream sector is bound by a special Joint Venture arrangement between the state owned NNPC and five multi-national oil companies namely: Agip, Chevron, ExxonMobil, Total, and Shell. As of March 2, 2017, NNPC posted on its website, details of the Joint Venture arrangement with International Oil Companies (IOC's), the NNPC owns 60% shares of the partnership formed with each of the producing companies – **see exhibit 1**. It implies that the Nigerian NNPC is a major stakeholder in decision making and could demand for the re-structuring of the industry. The other type of contract arrangement that exists in Nigeria, however, is the production sharing contract - between NNPC and the multinationals that explore and produce crude oil from Deepwater fields. The former arrangement – JV, focuses only on onshore and shallow offshore hydrocarbon assets.

The organizational structure of the Nigerian mid-stream and downstream industry is centralized with weak and fragmented subordinate units.

3.2 The role of the Government in the Nigerian Downstream Petroleum Industry

Since 1970 after the government took ownership of refineries in Nigeria, they have been poorly managed. Some of the issues are attributable to problems of centralization of authority and decision making. In a large complex organization like NNPC that caters for the demand of over 188 million consumers, history has shown that the adopted centralized approach to managing the corporation has not worked. Unfortunately, Government took over roles that are better handled by the private sector and subjected the downstream sector to centralized organizational structure of management. Several researchers have challenged the centralized structure of managing organizations - Vitez (2017), Meagher and Wang (2008). Chikwem (2014), in a study cited comments by the former Nigerian President of Independent Petroleum Marketers Association of Nigeria (IPMAN), who stated:

> *"Government involvement in the management and ownership structure of the refineries and downstream logistics infrastructure gave rise to a regulated regime that was characterized by: Inadequate supply and distribution of petroleum products, pricing regimes that did not allow for recovery, acute products scarcity which often lead to long queues at filling stations".*

3.3 Challenges with the Nigerian Petroleum Downstream Industry

Apart from the problems captured in previous sections, other exogenous factors like pipeline sabotage and vandalism, corruption and diversion of petroleum products to neighboring countries contribute to the reasons why petroleum products are often scarce and unavailable to consumers in Nigeria.

The NNPC has four refineries with a total refining capacity of 445,000 barrels of oil per day (BOPD) – **see exhibit 2.** Despite the large amount of monies allocated by successive governments to revitalize the refineries, the refinery managers record high downtimes; operating sometimes below 22% of design capacity. Mordi (2017) stated that poor maintenance culture and diversion of maintenance monies by corrupt public office into private pockets explain why the refineries struggle to function on full capacity. In 2011 for example, 122 billion Naira; an equivalent of 1 billion dollars was wasted on refinery turnaround maintenance. Badmus et al (2012b) argued that poor turn around maintenance of the refineries affect yield and performance. Amongst other maintenance gaps, they cited the use of low quality water to run the refinery boilers; causing frequent failure and rupture of the boiler tube. However, If the refineries operate at full capacity, Nigeria will be able to meet its domestic demand for liquid fuel especially with actual energy consumption rate significantly lower than total daily production– **see exhibit 6.**

3.3.1 Pipeline destruction by Niger-Delta Militants

Another challenging factor facing crude oil refining in Nigeria is high militancy activity in the Niger Delta area; which disrupts scheduled pumping of crude oil through underground pipelines from point of production to the four refineries. Often, unemployed youths engage in pipeline vandalism; blowing up pipelines using dynamites and kidnapping oil company workers for ransom. In addition to losing crude oil production opportunity for the refineries, large volumes of the crude oil is spilled to the environment; causing pollution and death of vulnerable

aquatic plants and animals within the vicinity. Njoku (2016) in his study, argue that militancy activities in the Niger Delta region that result to pipeline vandalism has caused significant impacted on the socio-economic development of the country.

3.3.2 Imported Petroleum Products Hoarding and Diversion

Furthermore, hoarding and diversion of products to neighboring countries where pump prices are higher; constitutes another roadblock to liquid fuel supply and distribution in Nigeria. Preston-Efedue (2017), for example, reported incidents of petroleum products diversion to Lomé, a neighboring country, by oil marketers and not in Lagos – Nigeria. IPMAN (2016), acknowledged this trend as well as the negative impact on government effort to solve the problem of product scarcity in the country. The group vowed to checkmate the menace by supporting the government with product vessel monitoring and inspection. Higher product margins on the other side of the land borders incentivize hoarding and diversion of imported petroleum products. In January 2016, for instance, one liter of fuel in Nigeria was sold for N145 – regulated price, while in Niger republic, it was priced N400. The significant difference in pump price in the neighboring countries encourage licensed product marketing and distribution companies to hoard and divert the products across the land boarders where they are sold at higher margins. Another related trend challenging product marketing and distribution is the attempt by marketers to gain market power. As cited by Stiff et al (1975) in their study of the secondary social and economic impact of scarcity and hoarding

of commodities in the market, they argued that the news of scarcity could spread through the media encouraging hoarding and causing panic in the market.

3.3.3 Activities of Petroleum Product Cartels

Because there are limited number of companies licensed to trade, import and distribute petroleum products in Nigeria, petroleum product marketers easily form cartels and as a result decide to hoard products to create artificial scarcity. With scarcity, a parallel market is created - one sells at government regulated price and the other sells at black market price. Whenever the cartel sets in "panic buying" in the market, many filling stations respond by reserving significant volume of refined petroleum products for black market transactions maximizing marginal revenue. Although Government has made several attempts to curb these activities through arrests and closure of culprit filling stations, it is still prevalent and remains a key cause of petroleum product scarcity in the country.

3.3.4 Activities of Corrupt Government Officials

These are the numerous problems confronting local refining of petroleum products in Nigeria. To respond, the government before 2011 decided to start importing petroleum products from refineries in Europe and other parts of the world to meet domestic demand. However, this approach had its own challenges. After few months of implementation, increasing cases of corruption by individuals in government that issue licenses to petroleum product importers for bribes started to surface. Sequel to these challenges, the NNPC started importing petroleum products using newly registered traders as middle men. On several occasions too, the traders collude with corrupt officials in government and report

unverified and superficially made up volumes of imported petroleum products. Later, the follow through to lay claim on large sums of money from the government. The proceeds are then shared by collaborators involved in the fraud. In extreme cases, products are not even imported but claims are made for payment. Premium times in its web publication (2017), reported company's caught in the fraudulent act oil subsidy fraud between 2009 and 2011. The country paid subsidies for 59 million liters when it consumed 35 million liters. According to the publication, over N2.5 trillion was spent in 2011 on subsidy, a 900% increase from a year before.

3.3.5 Existence of Poor Fiscal and Monetary Policies

Another challenge to liquid fuel sufficiency in Nigeria is with weak fiscal framework. This causes occasional shortages of Forex from the CBN. The global drop in oil price had a significant effect on the Nigerian economy. It reduced the country's foreign exchange earnings and Naira was remarkably weakened against the dollar. As a response to the abysmal drop in the value of the Naira, CBN held back dollar from the economy. The policy caused recession and inflation which further depreciated the value of the Naira against the dollar. With regulated fiscal policy trend, petroleum products trading companies struggle to buy foreign currency - dollars for product importation from Europe or Asia.

3.4 Attempts by Government to Reduce Corruption in the Industry

A research by the National Resource Governance Institute (2015), the Nigerian government, generally, has tried to meet domestic demand for liquid fuel using four methods:

1) Local refining of crude oil by NNPC. Refined petroleum products are then sold to local licensed marketing companies who later sells to retail outlets. Also, some of the refined products are allocated and sold to consumers through NNPC owned filling stations.
2) The open account system: Here, the Petroleum Products Marketing Company (PPMC), a subsidiary of NNPC works closely with traders to import products and in return NNPC pays in-cash.
3) The Petroleum Products Pricing and Regulatory Authority (PPPRA) issues license to private marketers to import and sell directly to wholesale and retail buyers. In this arrangement, NNPC is not involved.
4) NNPC swaps crude oil in a battered arrangement for petroleum products like gasoline, diesel, jet oil, and kerosene instead of money.

Across the various methods adopted by NNPC to meet local demand for liquid fuel, there have been one problem or the other that ends up creating petroleum product scarcity. As stated by NRGI (2015), for instance, the country's refineries operated at 20% of installed capacity, making the first option unsustainable. With the second option, traders were owed over $3 billion in debts; prompting financing banks to refuse calls for support by the traders, thus discouraging importation by the traders as old debts were not paid for over 1,000 days. With increasing product scarcity across the country and prolonged mass demonstration against the government, the NNPC corporation needed a new mechanism to import refined products. Thus, they turned to option 4 - crude oil swapping. This involved two basic types of contracts: The first is known as the

Crude-Oil-for-Refined-Product-Exchange-Agreement (RPEA) while the second contract type is the Offshore Processing Agreement (OPA). The former involves allocating crude oil to a trader who is expected to import petroleum products worth the same amount as the crude oil allocated. The cost of importation and other fees are deducted as a way of normalizing the transaction on both ends. In the later, OPA, the trading company will lift and export agreed volume of crude oil to her refinery and return refined petroleum products. In most cases, the refining company pays cash for products the Nigerian government does not need. While these crude oil swapping methods could be effective in making petroleum products available to consumers in the short-term, however, it is unsustainable on the long term. For example, due processes were not followed in awarding contracts; making the process open and vulnerable to high levels of corruption. Between 2010 and 2014, Nigeria traded more than 352 million barrels worth of oil, estimated at $35 billion, Quartz Media (2015). Contract awarding processes are opaque and hardly published. In 2014, however, the governor of the Central Bank of Nigeria (CBN), Lamido Sanusi cited unquantified losses in oil revenue as a result of the swap arrangement. In his words, he said *"The swaps are not properly structured, monitored, and audited",* Quartz Media (2015).

These supply challenges are chiefly responsible for the shortage of petroleum products in the country. Often, filling stations are packed with liquid fuel consumers that queue for hours to fill tanks of their vehicles and electricity generators.

Chapter 4: The 3 Node Structure Model (NSM)

4.1 Overview of the 3 NSM

The 3 NSM is a proposed framework to re-structure the Nigerian petroleum downstream sector. It offers a technological and policy based solution to current challenges of petroleum products supply and distribution in Nigeria and It is based on the Multiunit structure approach of management. The new structure aims to reposition Nigeria as a hub for petroleum products refining in the region as well as a global net exporter of petroleum products such as jet fuel, prime motor spirits (PMS), diesel, and kerosene. It is follows a 3 strategic node concept that vertically integrate the upstream sector of the petroleum industry into a more efficient downstream sector. It would involve the creation of 3 subordinate and autonomous units that rely on strategic private-public-partnership arrangements across the petroleum production and refining value chain. Local and international petroleum companies will be expected to play a dominant role in achieving the transformation initiative.

The new structure encourages collaboration between international oil companies and major downstream private sector players in achieving a liquid fuel sufficient Nigeria. Operational efficiency and organizational capabilities of IOC's operating in the country as well as expertise of downstream private sector

companies could help capture, create and deliver significant value in Nigeria's downstream industry.

The 3 NSM comprises of:

1) Downstream – Upstream (D-U) subunit,
2) Downstream-Midstream (D-M) subunit, and
3) Downstream-Downstream (D-D) subunit

Unbundling the sector could have powerful effect on the supply dynamics as well as investment behavior of private companies in the sector. offers a unique fit-for-purpose solution to most of the problems confronting the petroleum downstream sector in Nigeria. If it is fully implemented, more mid to large size private companies will invest in the sector, which in turn would create millions of jobs for teeming youths and trigger growth in the economy. A schematic of key components of the new structure is shown below in **exhibit 9.** The new structure as illustrated below would require: construction of new refineries at the operational base of selected IOC's.

4.2 Proposed Product Allocation framework of the 3 NSM:

The proposed product allocation framework of the 3 NSM assumes that the five major oil and gas companies in Nigeria would be encouraged to participate in the implementation and roll of the new structure. With over 60 years of crude oil exploration and production experience in Nigeria, it is reasonable to further assume that they have the organizational capability and the operational excellence to support technical and operational aspects of the new structure. The major oil companies that have been active

in Nigeria since her independence include: Chevron, Total, ExxonMobil, Shell and Agip. If their daily production rates are represented by the letters C-Chevron, T-Total, E-ExxonMobil, S-Shell and A-Agip, thus, total daily crude oil production in Nigeria would be represented as :

$$G = C + T + E + S + A + O \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\,(1)$$

Where G - Daily Total Production (BBL),

C - Chevron's Production (BBL)

T - Total's Production (BBL)

E - ExxonMobil's Production (BBL)

S - Shell's Production (BBL)

A - Agip's Production (BBL)

S - Shell's Production (BBL)

O - Indigenious Companies Daily Production (BBL)

O represents crude oil production by indigenous companies that operate marginal fields in the country. If we assume *O* to be negligible due to their relative low production volumes,

Then, *eqn (1)* could be expressed as:

$$G = C + T + E + S + A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\,(2$$

4.3 The Chi-factor

On the demand side of the market, let "g" represent domestic demand, and "x" – additional export capacity.

Therefore;

$$c + t + e + s + a = g + x \quad \ldots\ldots eqn\ (3)$$

Where *c, t, e, s, a* are the daily production volume that must be allocated to refineries in order to meet domestic and regional demand for refined petroleum products. In this research, these variables will be referred to as the "Chi-Factor" of each refining facility.

Mathematically, the Chi-Factor can be derived as function of 3 variables: the daily domestic demand *(g),* daily export demand *(x),* and Nigeria's total daily crude oil production rate *(G). g* can be estimated using various stochastic models. For simplicity, the variance and standard deviation of historical demand data could be acquired at petrol stations and other outlets across the country. This could be used to provide a reliable estimate of demand – domestic and regional and as time goes on, the demand estimation model could be designed to average out; thus, calculating more precise estimates of demand.

Solving equations 2 and 3 simultaneously, multinational companies could determine the Chi-factor or the volume of crude that should be allocated to the refinery. For example, Chevron's Chi-factor can be estimated as a ratio of total production and demand. i.e.

$$c = \frac{C(g + x)}{G} \quad \ldots\ldots eqn\ (4)$$

The Chi-factor of each participating multinational company when translated in context, represents the Minimum Daily Crude Oil Volume Allocation (MCVA).

Thus;

$$\sum_{i=1}^{n} MCVA = g + x \quad \ldots\ldots eqn\ (5)$$

Where i≥c, t, e,s,a

Also;

$$if \quad c + t + e + s + a = MCVA \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ (6)$$

$$\therefore \quad MCVA(c) = g(c) + x(c) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ (7)$$

$$Where\ c = Chevron's\ share\ of\ the\ refining\ obligation$$

However, the allocation process will require optimization. For example, in a situation the refineries record long unplanned downtime, a system has to be developed to re-allocate product refining volume to other refineries. This could happen as a result of Niger-Delta militant activities or operational challenges. In extreme cases, disruption of significant production volume could result to the allocation of insufficient volume of crude oil to refineries.

Chapter 5: Implementation of the 3 NSM in Nigeria's downstream sector

As recommended in earlier sections, the Nigerian government through the NNPC would need to spearhead the implementation of the proposed 3 node structure model with support from other key stakeholders like the NNPC, International Oil Companies (IOC's), and Foreign and Indigenous Private Oil Companies. Specific actions these organizations could take to support the process are shown in the table below:

S/N	Key Stakeholder	Specific projects or functions to enable the 3 NSM in Nigeria's petroleum downstream sector
1	NNPC	a) **Oversight / Regulatory function:** Set a strategic milestone of achieving liquid fuel sufficiency ad net export status of refined petroleum products by 2023. Also, develop key performance indicators as well as timeline to achieve these milestones. The NNPC on behalf of the Government should set-up an autonomous management team for each of the subunits. The subunits will need to be managed as an SBU under the management of managing directors (MD's), who would be fully engaged and aligned to the strategic objective of repositioning the sector as a global hub for petroleum products refining and exportation by 2023. The Downstream-Upstream Subunit will oversee the registration of modular and conventional refinery

		operators, ensure they meet a minimum set of criteria to get license to operate and ensure they are strategically located within the operations base of the IOC of their choice. The D-U subunit will also ensure that the Chi-factor of the companies are estimated and that there is adequate daily crude oil allocations to their refineries. b) **Petroleum Downstream Reform Bill:** The restructuring initiative would require the consent of the legislature and as a result, it will be pertinent that a bill focused only on the downstream sector is presented and passed by the Nigerian Senate. It could be considered a priority bill since a significant amount of national foreign exchange earnings could as well be derived from the petroleum products export market.
2	IOC's	a) **Technical and Operations Partnership:** To enable local companies to participate in the industry, IOC's must be encouraged to work in partnership with international companies so that best practices, organizational capacity and lessons can be passed unto their local counterparts interested in running a refinery.

5.1 Downstream – Upstream (D-U) subunit

The operational and structural scope of the D-U starts from crude oil terminal storage facilities of IOC's to the site where the new refineries will be constructed. Typically, when multinational oil companies produce crude oil from the well heads, the oil is transported via flow lines to large storage tanks situated at the operational base of the producing company. The crude oil is allowed to settle to enable further separation of water and gas from the multiphase fluid. After treatment, crude oil is pumped out of the tanks using high capacity pumps into ships for evacuation to predetermined locations around the world where they are sold.

However, the proposed 3 NSM recommends a modification of produced crude evacuation network of IOC's to incorporate a node on the line where some volume can be diverted for commercial refining purposes.

This could be easily achieved by installing a valve or set of control valves to connect the crude oil evacuation facilities to the refinery. The volume of crude oil that would be diverted should be equal to the minimum crude oil allocation volume (MCVA) as discussed in section 4.3 above. On the part of the Government, it is recommended that they play an oversight function by coordinating the allocation of the daily required volume of crude to the refineries sequel to the estimation of g, daily domestic consumption rate, and x – additional volume to meet regional demand for petroleum products.

Adopting this new structure would require building refineries in Escravos, Chevron's Nigerian operational base, Forcados, Shell's operational base, and

Eket where Mobil's operation is located. In this revised understanding with IOC's, the NNPC's D-U unit would have a non-operating interest in the JV partnership while the IOC's and/or capable third party companies operate the refineries – a similar form of arrangement that exists in the upstream sector. Thus, It will be reasonable to employ their expertise, operational excellence and efficiency to manage refineries since the same IOC's own and operate similar facilities in other parts of the world.

5.2 Downstream-Midstream (D-M) subunit

The downstream-midstream subordinate unit sits in-between the D-D and D-U subunits. It will comprise mostly of administrative and logistics planning since the bulk of the work here will be registering local, regional, and international petroleum products purchase companies. It will be responsible for marketing and distributing of refined petroleum products to registered independent private companies. The companies could be foreign or indigenous. As long as they meet the criteria set by NNPC to lift refined petroleum products from these bases, they will be issued lifting licenses. However, to ensure the objectives of this initiative are sustained, this subunit will work closely with the D-D unit to monitor and track companies that are registered to deliver petroleum products to Nigerian tank farms. The operations on this node will streamline costs associated with the evacuation of refined products to Nigerian shores. They will manage all planning and scheduling activities of the NNPC to ensure product tankers of licensed companies receive products for distribution on daily basis. Existing ship berthing facilities in these operational bases can be leveraged to effectively evacuate refined petroleum products.

5.3 Downstream-Downstream (D-D) subunit

The D-D unit will be responsible for monitoring and tracking petroleum products immediately they leave the refineries for discharge into storage tanks onshore or offshore for exported products. This unit will manage product tracking from the storage tanks to filling stations using technology. GPS enabled devices could be installed in all the floating, loading and supply vessels as well as all the land transportation tankers and fuel stations. This will allow for more transparency and accountability. The location of the products can be easily tracked and their geographical locations visualized in real time. Additionally, consumer friendly applications can be developed to help customers know which fuel stations have products and what quantity of products are remaining in for sale.

5.4 Requirements for Implementation of the 3 NSM

To effectively deploy the 3 NSM in Nigeria, the following reforms or requirements will need to be considered:

1) Revision of the current JV partnership arrangement between the NNPC and the IOC's to include operations in Node 1 of the new proposed structure.
2) Encourage participation of the private sector – local and international firms in Node 2 and 3 of the structure.
3) Ensure that IOC's capture the MCAV in their business plan cycle reviews.
4) Mechanism should be put in place to ensure projects receive adequate funding.

5) Provision of stable-longer term policy framework to incentivize industry investment and operations.

5.5 Evaluation of the 3 NSM using System Dynamics (SD)

Due to the complexities involved in the Nigerian petroleum downstream sector, a robust model that captures inherent multi-dimensional dynamics of the energy system is crucial in explaining how the 3-Node structure can offer a reliable solution to fuel scarcity and distribution challenges in Nigeria. System Dynamics as a tool comprises of functionalities that allow modelers to answer questions like what are the moving parts of a system? How can their causal effects be captured? what variables in the system show re-in forcing or balancing effect on others? And how can stakeholders and policy makers come to understand the whole system? Using System Dynamics, these questions and more could be effectively analyzed in a social, political, business or economic systems context. With System Dynamics, a simulation of the socio-economic complexities of the Nigerian petroleum downstream sector including important activities associated with refined product importation and consumption could be achieved. According to Sterman (2000), one can capture the dynamics of complex systems in a model if feedback processes, stocks and flows, time delays, as well as nonlinearities are discovered and represented as either variables, constants or exogenous factors.

The whole system as proposed can be modeled and analyzed using system dynamics. Despite the fragmented nature of the current state, an attempt was made to capture key dynamic components of the system. However, it formed the basis for policy recommendations captured in this work. Hidden causal effects and system feedback loops are highlighted and used to understand the impact of exogenous factors on model

variables like demand, investments, economic growth, unemployment rate, and boosting Foreign Direct Investment (FDI).

5.5.1 SD analysis of the Nigerian Petroleum Downstream Sector - Current State

The following section is used to discuss the major causes of fuel scarcity in Nigeria and it provides a focused evaluation of these causes using System Dynamics. Most of the policies suggested by previous governments have failed largely because policy makers are yet to approach the problem looking at the whole value chain. Evaluating the whole value chain with the view of highlighting opportunities for increase in job creation, reducing pipeline vandalism, eliminating petroleum product hoarding, growing the country's GDP and ensuring domestic utilization of petroleum products is translating to economic growth in the country can be accomplished using System Dynamics. **Exhibit 8** shows the causal loop diagram of the current state of Nigeria's downstream sector while **exhibit 4** shows the variables, stock and flow entities used in modeling the system. The exhibit shows the system stocks, system flows as well as key variables that create powerful causal effect on policy objectives. As long as the impact of negative reinforcing loops stay higher than that of the positive loops in the system, the value chain of petroleum products distribution will continue to experience shortages in supply especially when any of the causal factors in the system is manipulated by major stakeholders in the value chain, For example, hoarding of a significant amount of imported fuel would change the supply pattern, therefore creating artificial scarcity. More so, the model as shown in **exhibit 8** suggests that a reduction in importation will result to an increase in demand. An increase in demand will result to an increase in

inflation; which reduces net household income since households will purchase energy at inflated rates to meet daily basic needs. Additionally, with the current system of direct purchase-direct sale (DPDS) also known as the crude oil swapping system, more crude oil exports will translate to higher importation of refined petroleum products. Higher importation of products means more subsidy payments by the Government to middle men and companies that negotiate crude oil swap on behalf of NNPC. Higher subsidy payments, discussed in previous sections, create negative impact on GDP, economic growth, and unemployment rate. With high rates of unemployment, youths from crude oil producing communities are incentivized to vandalize crude carrying pipelines in demand for cash settlements or contracts in the petroleum production value chain. When the pipelines are blown up, total national output drops; causing a shortage of crude for the DPDS swap arrangement. The loop continues to cycle round over periods with negative feedback effects on the economy, the supply chain and consequently product scarcity across the country.

5.5.2 SD analysis of the Proposed 3 NSM – Future State

In this section, system dynamics is used to demonstrate how the 3 node structure model can be implemented. Given that the key stakeholders in solving the problem of liquid energy supply scarcity in Nigeria is the government and the private sector, **exhibit 9** shows reinforcing feedback loops that can be leveraged by both parties through policy reforms and commitment change in the sector. According to the illustration shown below **- exhibit 9**, 7 feedback including:

1) **The subsidy loop:** The subsidy loop sits in the D-U subunit of the 3 node structure model. Within this subunit, the total production rate increases the build-

up of crude oil volume (Stock) for the refineries while the refining capacity – refining rate (Flow) decreases crude oil volume for refining. In context, total production rate(BOPD) is estimated by adding production from new subsidy wells (BOPD) to production from existing legacy wells (BOPD). The result is multiplied by a pipeline vandalism factor – 1 to 0 depending on the scenario. The subsidy comprises of endogenous and exogenous variables in the sector that act together to produce a subsidy payment reduction effect. More number of additional wells that are drilled to augment legacy well production would result to higher volume of crude oil available for the refineries. The main concept espoused in this loop that calls for policy reform consideration is the ability to transfer current subsidy payment to companies that decide to invest in the sector. Government can reduce corruption in this section of the value chain by increasing transparency through subsidization of technology. To further ensure monies are not moved between parties that would be involved in growing this section of the industry, a policy that allows for subsidy of cost of constructing and operating new refineries at operational bases of IOC's can help make affordable petroleum products available for domestic consumption. This can be achieved by allocating more crude oil volumes to refineries with a cost structure that offers payment for the difference between fair value and regulated pump price value. Huge savings can be made from agent companies that get payments for petroleum products shipping and customs costs- see **exhibit 9**

2) **The pipeline vandalism and unemployment loop:** Another loop that is situation within the D-U subunit loop is the pipeline vandalism and unemployment

loop. Here, more subsidy well drilling, more jobs are created, majority of the local youths in the Niger-Delta get employed and the probability of pipeline destruction is reduced – **exhibit 9** below.

3) **The Investment loop:** This loop saddles between the D-U and the D-M subunits. It is a very critical loop in the 3 node structure model. If well implemented, it will open up the sector to foreign direct investment (FDI) as well as local investors. This subunit would require a lot of policy changes that attract investors. With the allocation of sufficient amount of crude oil for refining purposes, multi-national refining companies will be incentivized to invest in refineries. Therefore, increasing capacity of Nigeria to produce and distribute enough for domestic consumption and perhaps export to neighboring countries – **exhibit 9** for more details.

4) **The Poor Turn Around Maintenance (TAM) loop:** The poor turn around maintenance loop addresses the challenges faced by the government in keeping up with the existing refineries. The issue of diversion of allocated funds for TAM by officials in authority will be reduced with the 3 node structure model. Since the private sector invests capital and oversees the running of the facilities, it is expected that maintenance and operating cost will be prudently recovered from sales of product. As shown in **exhibit 9** below, Increase in the number of refineries will cause an increase in market competition. With high market competition, companies will ensure that their refineries are efficiently maintained and downtime is reduced. Furthermore, this loop has the capacity to effectively drive down commodity price for consumers.

5) **The Hoarding and Diversion loop:** The hoarding and diversion loop will be largely impacted with technology adoption. With the installation of real time tracking or monitoring devices in the vessels that evacuate refined products from point of refining, the government is able to track destination and volume of tankers as they leave the loading docks for tank farms on the shores. These tracking devices will help reduce the risk of vessel vandalism or pirate attack. Reduced shipment risk will translate to a reduction in Loss Distribution Opportunity (LDO) and ultimately an increase in shipment rate (BBL/D). See **exhibit 9**
6) **The Regional Export Market loop:** According to **equation 3** above, the model makes provision for exportation of excess capacity to regional markets. Currently, most of Nigeria's neighboring countries as well as members of the ECOWAS nations import refined petroleum products from Europe. Refining petroleum products locally in Nigeria for the ECOWAS regional market will help these countries save cost from long distant shipment of products from Europe. With high demand for refined products by her neighbors, increase in sales will have a positive causal effect to the Nigerian economy.
7) **The Domestic Demand Loop:** The domestic demand loop is the most pertinent to ordinary Nigerians and indirect consumers. As demand for domestic consumption of petroleum products grow, the net availability of the product reduces. This in turn creates pressure for more investors in the sector. Without sufficient capacity to meet this demand, the Nigerian economy will slow down as inflation increase with low micro-economic activity. See **exhibit 9.** Details of the

variables, stocks and flows used in preparing the model in shown on **exhibit 5a, 5b and 5c.**

5.6 The 3 NSM Value proposition – Business Case

The 3 Node structure model offers a promise of opportunities for private companies to flood the Nigerian downstream sector and compete for market share – both locally and regionally. Investors can key into opportunities in either the D-U subunit, D-M subunit, or the D-D subunit. The following business case analysis is limited to the D-U subunit and for a simple illustration of the business case, I assumed costs and operations of a 350,000 BOPD and 600,000 BOPD refining capacity refinery. It is also assumed that the refinery is located within the operational base of IOC's and as a result cost of shared production evacuation facilities is negligible. For instance, berthing facilities, product discharge pipelines and so on. Other assumptions are that consumption will follow a historical incremental rate. Using a business timeline of 12 years, a trend of best fit was established following actual historical data on petroleum product consumption - **exhibit 11.** The plot was used to come up with the empirical model below;

$$Y = 3.4922x - 6710.8 \quad \ldots\ldots eqn\ (8)$$

where y = consumption rate

and x = time (years)

Furthermore, additional consumption capacity was built into the model to account for any potential shortfall between consumption and demand, and potential for regional supply of petroleum products. With Nigeria's total domestic consumption estimated at approximately 350,000 BOPD, the business model was prepared to include a second

scenario with refining capacity of 600,000 BOPD. With regards to oil price, three price scenarios - $30, $45, and $60 per barrel of crude were sensitized **exhibit 3** and on subsidy payment amounts, scenario cases for – N0, N100, N200 were evaluated. The naira payments for subsidy were converted to dollars to ensure that all the analysis were consistent. For example, N0 Naira subsidy payment will default to a petroleum product pump price of N145 in the model. While N100 and N200 subsidy payment will translate to a pump price of N245 and N345 in the model by adding the amounts to current pump price of N145 per liter respectively.

Following the earlier stated assumptions, 18 scenarios were simulated and only 3 show positive Net Present Value (NPV) and Return on Investment (ROI).. Sensitivity on capacity show that refineries with capacity below 600,000 BOPD might not be profitable – economics of scale effect. Also, on oil price, at lower oil prices - $45 and $30, two scenarios showed positive ROI and NPV because the price of the main cost element, crude oil, is reduced. **exhibit 3**, consists of the combination of sensitivity variables used to evaluate the viability of a refinery in the model. Result of these studies are shown in **exhibit** 2 below.

5.7 Other dimensions to the implementation process

5.7.1 Policy, Political & Regulatory reforms

Successful implementation of the 3 Node Structure Model would require a robust financial support structure for private companies that show interest in the sector. To enable their operations in the sector, favorable cost of capital and loan structures has to be developed. However, to incentivize financial institutions to participate in the sector,

existing policies, political concerns, and regulatory guidelines will need to be revised in the sector.

A major factor in attracting both foreign direct investors and indigenous investors is political stability. As a young democracy, the investors share some skepticism and reservations before they Nigeria as a potential investment destination. Concerns over instability of government policies, risks, and high default probability of the government tend to push them away from investing. But for about 18 years since Nigeria returned to democracy in 1999, the system has been increasing stable. Also, as a democratic country, major policy reforms would need to pass through the senate for review and endorsement. Recommended reforms that would enable smooth adoption and implementation of the solution includes 1) a legislative bill; proposing that the downstream sector be unbundled into three strategic nodes as earlier mentioned in the research. 2) A bill revising the provisions of the JV arrangement with multi-national companies to include co-location of refineries within the operational base of the IOC's, and 3) A bill adopting the use of real time tracking devises to monitor cargo movement, volume of refined products that are refined and distributed across the country.

Another crucial dimension to consider is revising existing regulatory policies. If regulatory compliance is seen as an organization's ability to adhere to laws, specifications, and policies, then some regulatory requirements to support the implementation of the 3 NSM must be looked into. Some of them includes – 1) Compliance with the MCAV estimates by the IOC's in Nigeria and adherence to work closely with refineries in their operations bases to refine assigned MCAV. 2) Compliance with the MCAV estimates by Indigenous petroleum exploration and

production companies 3) The government or NNPC to oversee and ensure every stakeholder in the value chain play their part in the process. All stakeholders in the sector must be encouraged to work together so as to agree on fit for purpose compliance performance metrics and milestones are developed and used to track compliance going forward.

5.7.2 Financial

With political stability, new policy and regulatory frameworks, the government will also need to engage financial institutions within and outside the country. The government could help negotiate investment friendly interest rates for capital on behalf of interested private companies. The government could co-invest to further dilute any perceived risk and most importantly build confidence in investors. Institutions like the World Bank – IFC, African Development Bank, Private Equity, Venture Capital backed start-ups and Commercial banks could as well sponsor investments in any of the three strategic nodes. Thus it is assumed that with political stability and favorable investment policy and regulatory frameworks, financial institutions will be will to allocate money to drive investment in Nigeria's downstream sector.

5.7.3 Operations

The operational aspect to the model implementation presents enormous opportunity for investors to participate in either the D-U, D-M, or the D-D subunits in the sector. In this category, private companies are encouraged to work closely with IOC's. Depending on whether they were licensed as operators of modular refineries or operators of conventional refineries, they are subsequently matched to IOC's. The expectation is that they will refine at a minimum, the MCAV assigned to the IOC hosting the refinery. More

so, companies that are currently importing refined petroleum products into Nigeria from Europe and other parts of world could be given licensing priority. Instead of being importers of refined products, they could become net exporters of products and their market size will grow to include additional consumers in the region and beyond. Approaching the transition this way will ensure that their businesses are not affected by the proposed 3 node structure model.

5.8 Nigerian Government incentive to adopt the 3 node structure model

- Bring lasting peace in the Niger-Delta oil producing area with increased employment rate amongst the youth population
- No incentive to vandalize pipelines since refining now occurs at the operational base of IOC's
- More Foreign Direct Investment in the sector will attract more revenue with taxes
- Significant savings from shipping and transportation costs
- There is more transparency and accountability is the downstream sector

5.9 SWOT Analysis of the 3 node structure

To further evaluate the capacity of the new structure in solving the problem of fuel scarcity and distribution in Nigeria, a SWOT analysis will be conducted to highlight its strengths, weaknesses, opportunities and threats. The intent is to show

Strengths:

- NNPC has controlling shares in the JV arrangement. Executive decisions by NNPC will always almost be considered for implementation.

- Real-time monitoring and tracking of petroleum products will be enabled
- The proposed consumer app will help eliminate long queues in fuel stations since consumers will be able to view fuel stations with petroleum products.
- The impact of pipeline sabotage and destruction of oil facilities on refining capacity in the Nigeria will be significantly reduced since refineries will be located at production gathering station.

Weakness:

- IOC's might not be willing to review existing JV partnership agreement to include crude oil refining.
- Increases in price of oil will reduce refinery margins and potentially affect profitability of the refining business.

Opportunities

- It will significantly reduce corruption in Nigeria's petroleum downstream sector
- The new structure will create an additional forex earning window for Nigeria
- Refinery operations knowledge transfer to local employees
- Nigeria will become a global hub for crude oil refining
- Many skilled and unskilled jobs will be created for teeming youths if refineries are located in the Niger-Delta.

Threats

- Powerful interests in government and private sector whose businesses are built around the current structure will be threatened by the re-structuring.

Chapter 6: Summary, Conclusion, and Recommendation

6.1 Summary

A review of the main causes of fuel supply and distribution challenges in Nigeria was carried out in this study. Also, the effectiveness and efficiency of the centralized structure of Nigeria's petroleum downstream sector was critically evaluated and a 3 Node Structure Model was proposed as a solution to ensuring efficiency in the supply and distribution of liquid fuel in Nigeria. A Chi-factor was developed to automatically allocate minimum volume of crude to refineries. This is to ensure that the domestic demand for petroleum products is met, at the minimum.

Additionally, the study adopted the System Dynamics method of analyzing dynamic systems to highlight policy reform areas in the sector, the strength of the proposed structure as well as the weakness of the current structure in meeting the demand of the growing number of consumers in Nigeria and its regional block.

Furthermore, a business case evaluation was done to show the viability of investments in the sector. 18 Scenarios were analyzed and 3 show appealing NPV and ROI results.

6.2 Conclusion

The findings highlight the key causes of fuel scarcity in the country despite being on the top of the list of major oil producing countries in the world. Corruption, poor turn around maintenance of existing refineries, hoarding and diversion of imported petroleum

products and militant activities in the Niger Delta area where oil is produced in Nigeria are amongst the major causes of fuel scarcity.

A new structure for the Nigerian downstream sector – The 3 NSM has been proposed and shown to offer a promising solution to the challenge. Major policy changes and technology adoption in the sector will introduce efficiency and effectiveness in the sector.

Finally, this study demonstrates that if oil prices sell below $45, investment in the Nigerian downstream sector will be profitable.

6.3 Recommendations

1) The Nigerian Government should unbundle the downstream sector of the Nigerian Petroleum Industry.
2) The Nigerian Government should create the enabling environment for multiple players to participate and drive the liberalization of the Nigerian downstream sector - The 3 nodes in isolation offer unique investment opportunities for foreign Direct Investment.
3) New policies that encourage private sector participation in the industry is needed to ensure the success of any reform. For example, policies that enable easy access to capital for local refining companies to participate in the industry, Tax holidays for companies to grow FDI.
4) NNPC should privatize most of its assets in line with the 3 node structure model.
5) The government should work closely with the private sector to ensure the current JV agreement with IOC's is reviewed and expanded to include the D-U and D-M sections of the value chain.

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Exhibitions

Exhibit 1: Nigerian Joint Venture (JV) partnership formula for Upstream Exploration and Production Activities

Company	NNPC - %	JV Partners
Chevron	60	40
Total	60	40
Exxon Mobil	60	40
Shell	70	30
Agip & Phillips	60	40

Source: Adapted from Journal of Emerging Trends in Engineering and Applied Sciences(JETEAS) 4(4): 667-671, 2013

Exhibit 2: Design Capacity of existing Refineries in Nigeria

Refinery	Date of Commissioning	Design Processing Capacity (STB/Day)
Warri Refinery	1978	125,000
Old Port Harcourt Refinery	1965	60,000
New Port Harcourt Refinery	1989	150,000
Kaduna Refinery	1980	110,000
Total		445,000

Source: Adapted from Scientific Research. Energy and Power Engineering, 2012, 4, 47-52.

Exhibit 3: Business Case Scenario results for construction and operation of conventional refineries in Nigeria

Investment Scenarios	Oil Price	Subsidy Payments	Refinery Capacity	NPV	ROI
1	60	0	Domestic	-29.4	-237%
2	60	0	Domestic +Regional	-31.2	-215%
3	60	100	Domestic	-13	-163%
4	60	100	Domestic +Regional	-3	-114%
5	60	200	Domestic	2.5	-88%
6	60	200	Domestic +Regional	23.4	-14%
7	45	0	Domestic	-19.3	-199%
8	45	0	Domestic +Regional	-13.9	-158%
9	45	100	Domestic	-3.28	-117%
10	45	100	Domestic +Regional	13.4	-44%
11	45	200	Domestic	12.7	-35%
12	45	200	Domestic +Regional	40.7	120%
13	30	0	Domestic	-9.16	-192%
14	30	0	Domestic +Regional	3.3	-123%
15	30	100	Domestic	6.8	-78%
16	30	100	Domestic +Regional	30.6	72%
17	30	200	Domestic	22.8	36%
18	30	200	Domestic +Regional	57.9	267%

Exhibit 4: Variables used in System Dynamics analysis of Nigeria's Downstream Industry – Current State

System Dynamics Model Entities	Entity Type	Linked Loop
Storage / Volume in-Country	Stock	N/A
Importation rate	Flow	Economic Growth Loop
Consumption rate	Flow	N/A
Demand	Variable	Demand Loop
Inflation	Variable	Demand Loop
Household Income	Variable	Demand Loop
Crude Oil Export	Variable	Economic Growth Loop
Pipeline Vandalism	Variable	Economic Growth Loop
Oil Reserve	Variable	Economic Growth Loop
Youth Unemployment	Variable	Economic Growth Loop
GDP & Economic Growth	Variable	Economic Growth Loop
Subsidy Payments	Variable	Economic Growth Loop
Shipping & Storage Costs	Variable	Unemployment Loop
Demand Loop	Variable	Demand Loop
Unemployment Loop	Variable	Demand Loop
Economic Growth Loop	Variable	Demand Loop

Exhibit 5a: Variables used in System Dynamics analysis of the Proposed 3 NSM – Future State. Downstream-Upstream Subunit Section

System Dynamics Model Entities	Entity Type	Linked Loop
Oil Reserves	Variable	Subsidy Loop
Find New Oil Reserves	Variable / Exogenous	Subsidy Loop
Drill Subsidy Wells	Variable	Subsidy Loop
No of Subsidy Wells	Variable	Subsidy Loop
No of Legacy Wells	Variable	Legacy Well Loop
Average Oil Well Rate – Subsidy Wells	Variable	Legacy Well Loop
Average Oil Well Rate – Legacy Wells	Variable	Legacy Well Loop
Unemployment Rate	Variable	Pipeline Vandalization / Unemployment Loop
Total Production From Legacy Wells	Variable	Legacy Well Loop
Vol of Crude Swab for Tech Subsidy	Variable	Legacy Well Loop
Total Production from Subsidy Wells	Variable	Legacy Well Loop
Total Production Rate	Variable	Legacy Well Loop
Pipeline Vandalism	Variable	Pipeline Vandalization / Unemployment Loop
Total Produced Volume in an Operational Base	Variable	Pipeline Vandalization / Unemployment Loop

Exhibit 5b: Variables used in System Dynamics analysis of the Proposed 3 NSM – Future State. Downstream-Midstream Subunit Section

System Dynamics Model Entities	Entity Type	Linked Loop
Refinery Capacity	Flow	Poor Turn Around Maintenance Loop
No of Refineries	Variable	Poor Turn Around Maintenance Loop
Market Competition	Variable	Poor Turn Around Maintenance Loop
Investor Interest in Subunit	Variable	Investment Loop
Allocation to the Refinery	Variable / Exogenous	Investment Loop
Total Demand Volume	Variable/ Exogenous	Investment Loop
National Refinery Index	Variable	Investment Loop
Product Price	Variable	Poor Turn Around Maintenance Loop
No of Registered Vessels	Variable	Poor Turn Around Maintenance Loop
Loss Distribution Opportunity (LPO)	Variable	Diversion and Hoarding Loop
Volume of Products for Distribution	Variable	Diversion and Hoarding Loop
Risk of Vessel Vandalism	Variable	Diversion and Hoarding Loop
Shipment Rate	Variable	Diversion and Hoarding Loop
New Refineries	Variable	Investment Loop
Diversion and Hoarding Loop	Variable	Diversion and Hoarding Loop

Exhibit 5c: Variables used in System Dynamics analysis of the Proposed 3 NSM – Future State. Downstream-Downstream Subunit

System Dynamics Model Entities	Entity Type	Linked Loop
Total Volume of Products for Domestic and Regional Market	Stock	Regional / Domestic Export Loop
Export Rate	Flow	Domestic Export Loop
Domestic Demand Rate	Variable	Domestic Export Loop
Storage Capacity of Tank farms	Flow	Domestic Export Loop
Product Distribution Rate	Variable	Regional / Domestic Export Loop
No of Outlet Stations	Variable	Domestic Export Loop
Consumption Rate	Flow	Regional / Domestic Export Loop
No of Domestic Consumers	Variable	Domestic Export Loop
Net Product Available	Variable	Regional / Domestic Export Loop
Product Sales	Variable	Regional / Domestic Export Loop
Refinery Performance	Variable	Regional / Domestic Export Loop
Regional Export Loop	Variable	Regional Export Loop
Domestic Demand Loop	Variable	Domestic Export Loop
Economic Growth / GDP	Variable	Domestic Export Loop
Number of Outlet Stations in Nigeria	Stock	Domestic Export Loop
Distribution Rate	Flow	Regional / Domestic Export Loop

Exhibit 6: Petroleum and other liquids production and consumption in Nigeria – million barrels per day.

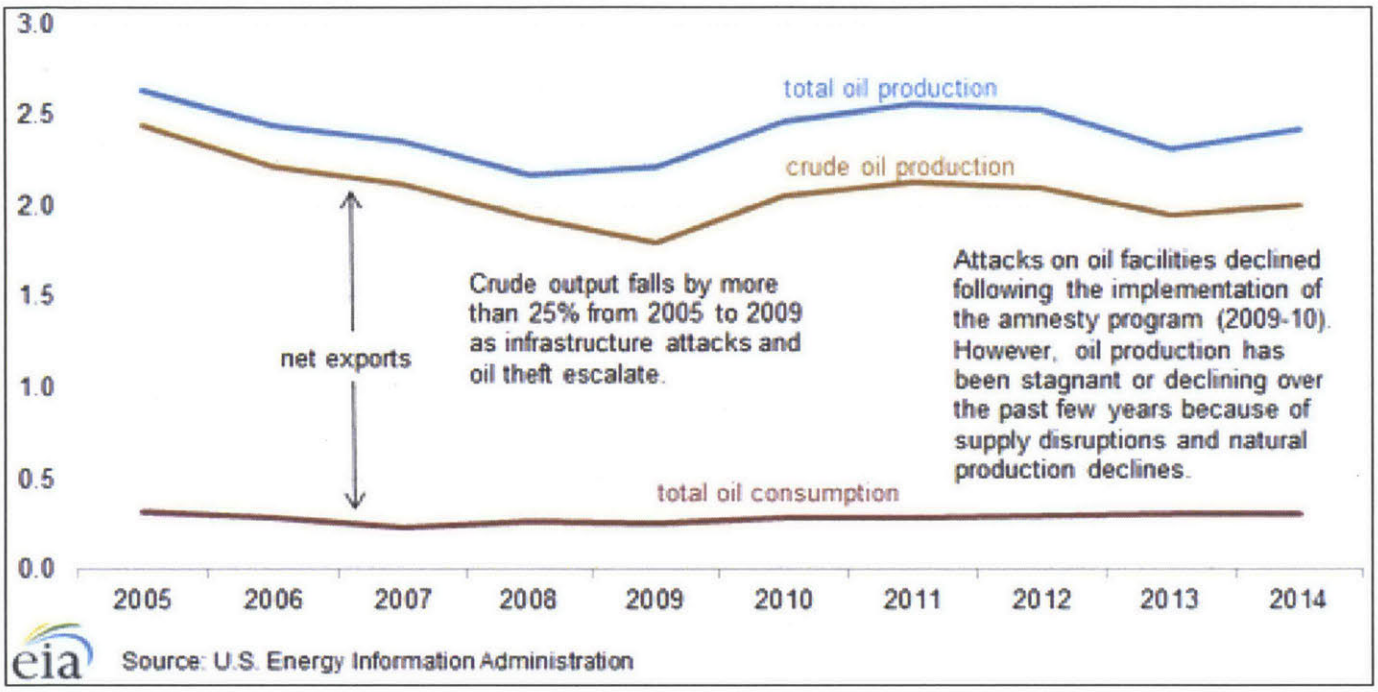

Exhibit 7: 18 Business Case Scenarios showing refinery Investment metrics

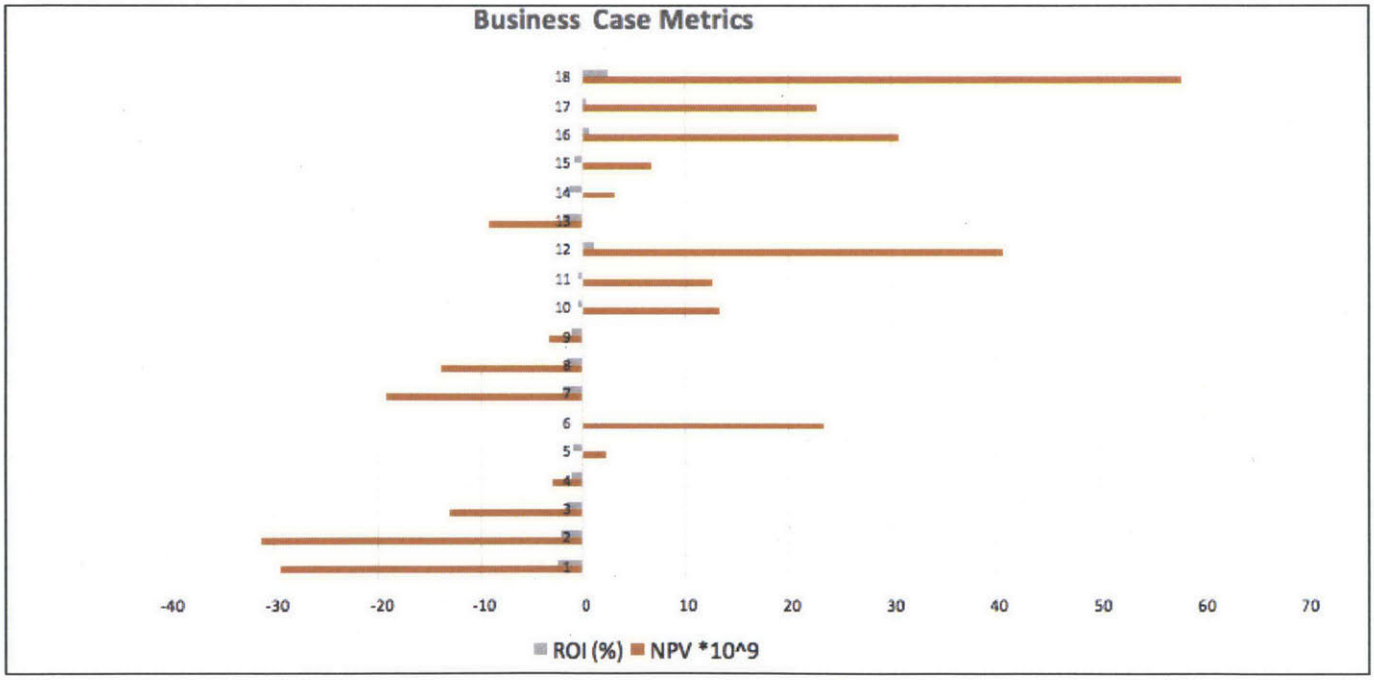

Exhibit 8: System Dynamics Model of the Nigerian Petroleum Downstream Industry – Current State

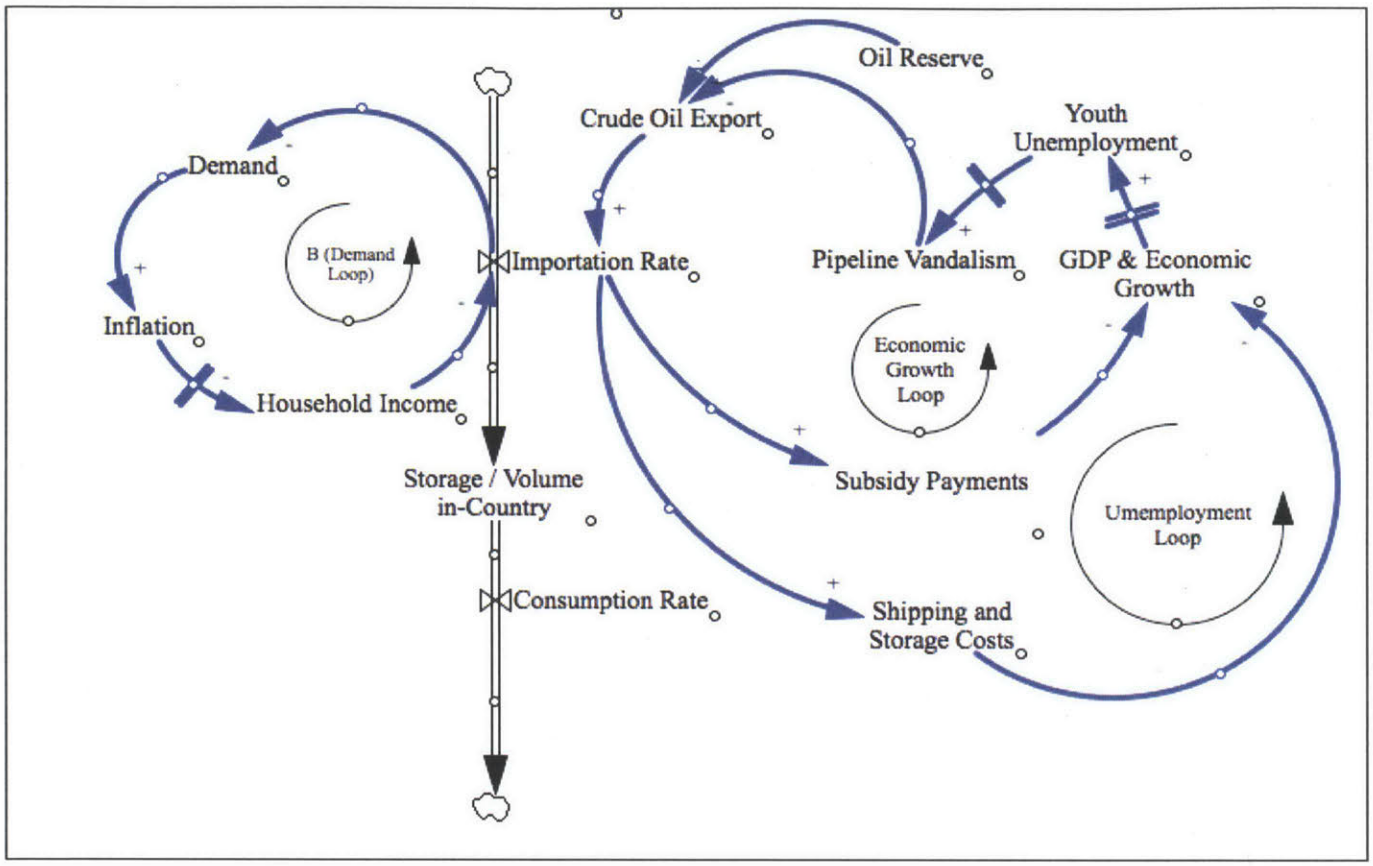

Exhibit 9: Conceptual Workflow Diagram of the 3 NSM

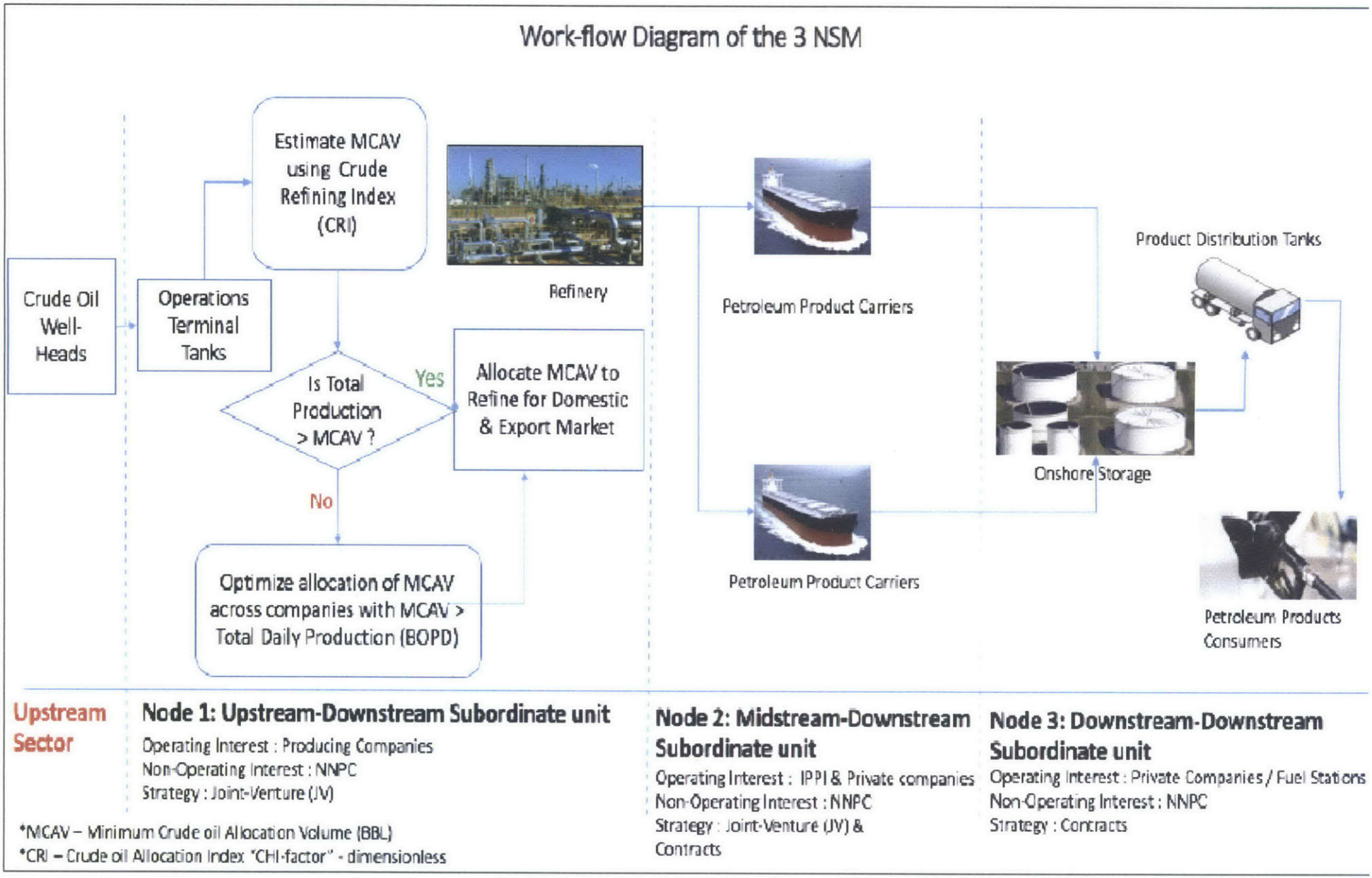

Exhibit 9: Conceptual Workflow Diagram of the 3 NSM

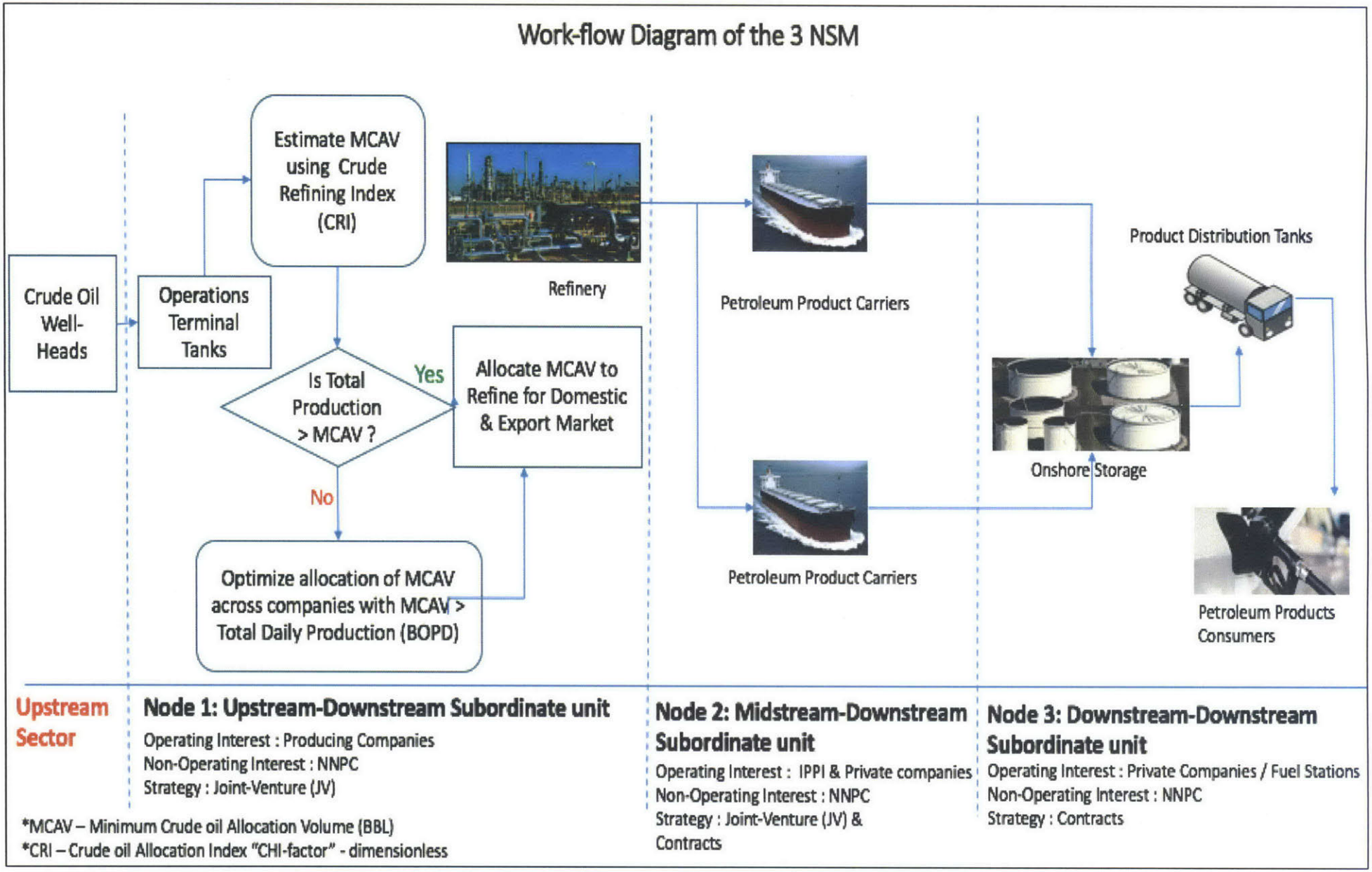

Exhibit 10: System Dynamics Model of the Nigerian Petroleum Downstream Industry incorporating the 3 NSM – Future State

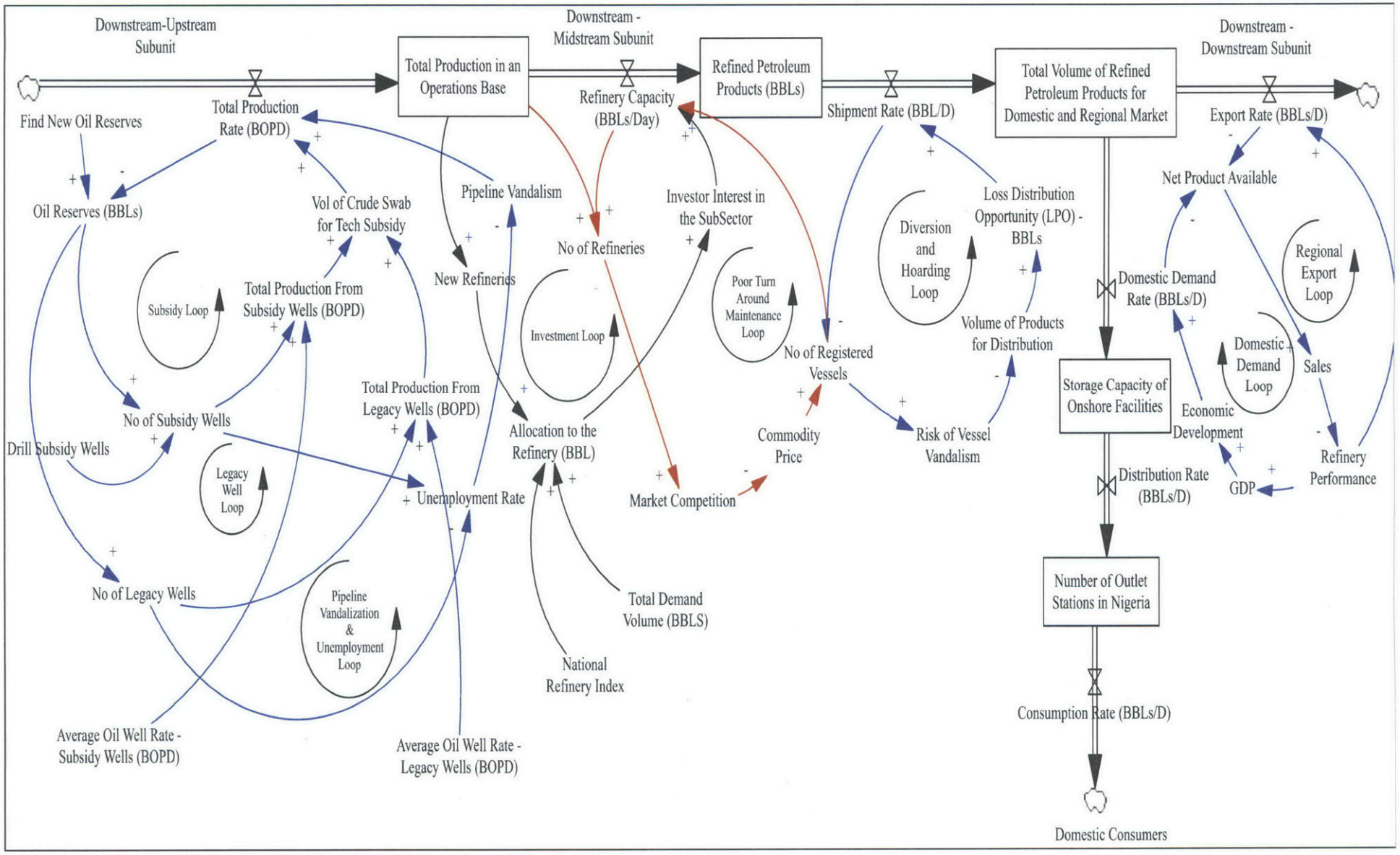

Exhibit 11: Forecast of liquid fuel consumption using best fit analysis