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Technological and Economic Perspective to the Modular Refinery Alternative

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ABSTRACT

Many countries have employed effective refinery planning for profitability and efficient utilization. In an attempt to stimulate similar achievements in Nigeria, the modular refinery alternative (MRA) was proposed. This study identified the critical technological factors influencing MRA in Southwestern Nigeria, assessed its engineering economy viability and determined the appropriate site location for the MRA in the region. This was with a view to achieving sustainable petroleum refining in Southwestern Nigeria. The study obtained data from thirty purposively selected energy industry experts' from academic institutions, commercial banks, government energy management agencies and energy management advisory firms in Southwestern Nigeria. Data obtained include technological specifications for modular refinery installation like refinery output capacity, refinery configurations, and crude oil specifications. Data for techno-economic feasibility of the project included capital, operating costs, interest rates, time and product selling prices. Data for the project location included locational factors, initial investment, raw materials and utility expenses, and other expenses. The data obtained were analyzed using energy planning and engineering economy methodology. The results showed that the most critical technology issues influencing MRA development in Southwestern Nigeria include refinery configuration, crude oil input characteristics, storage capacity, refiner's/investor's margin, and government incentives. These were all ranked 8 out of 10 on a 10-point Likert-like scale. The three modular plant sizes analysed (20,000, 40,000 and 60,000 barrels per day, respectively) gave positive Net Present Values (NPVs) of $5.96 Million, $39.48 Million, and $60.82 Million showing that the three options were economically viable. The Break-even Periods were estimated to be 14, 9, and 8 years, respectively, with Returns on Investment of 8.5, 37.2 and 37.3% respectively. Estimated plant site distances from the crude oil supply in Delta State were Ekiti (309.98 Km); Ondo (247.93 Km); Osun (388.7 Km); Oyo (408.46 Km); Lagos (424.51 Km) and Oyo (309.98 Km). The study concluded that 60,000 barrels per day MRA located in Ondo State was the most appropriate for Southwestern Nigeria (NPV = $60.82M, Break-even Period = 8 years, ROI = 27.2%).

Keywords: Modular Refinery Alternative; Engineering Economy Assessment; Petroleum Products; Mutually Exclusive Alternatives; Domestic Refinery Capacity.

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INTRODUCTION

A petroleum refinery is an industrial processing plant or an integrated group of manufacturing plants where crude oil is processed and refined into more useful petroleum products such as naphtha, gasoline, diesel fuel, asphalt, heating oil, kerosene, and liquefied petroleum gas (Gary *et al.,* 2007; Fahim *et al*., 2010). Process engineering plants generally convert some form of natural or synthetic material into finished goods or products for direct or indirect consumption by industries or the public. The American Petroleum Institute (API, 2006) asserts that petroleum refineries are large processing factories that convert crude oil into commercially valued petroleum products or petrochemicals.

Crude oil in its unrefined state is of limited value and use.Thus refining would be required to obtain petroleum products that are attractive to the market. Roussel and Boulet (1995a) and Fahim *et al.*, (2010), in their studies reported thatthe crude oil refining industry has petroleum refineries in various sizes and standard processing capacities (installed units), ranging from small topping and reforming refineries to sophisticated complex refineries. It was further pointed out that the petroleum refinery processing units perform four basic functions, which are: separation (fractional distillation); conversion (cracking); treatment and blending. In other words, petroleum refining is then classified as a multiproduct-producing activity which comprises a set of interrelated refining technological processes for the production of refined petroleum products. These refineries must be designed to handle a diverse range of crude oil from sweet to sour and light to heavy and also meet environmental and emission standards set by governments (Adiele, 2009; Fahim *et al.*, 2010). In an earlier study, Jones (1988) noted that aside from being a method of converting crude oil to its constituent products, refining is a way of adding value to petroleum. It is therefore an important link, in terms of making crude oil usable by energy appliances, and commercial operations of the refining industry.

The establishment and operations of the Oil refining industry in Nigeria dates back to 1959 with the construction of four (4) State owned refineries with a total installed total capacity (throughput) of 445,000 barrels per day (bpd) to refine crude oil into petroleum products for local consumption (Idigbe and Onaiwu, 2011; NNPC, 2013; DPR, 2013). These refineries were built in different years, locations and refining capacities: Port Harcourt I (built in 1965 with 60,000 bpd), Port Harcourt II (built in 1989 with 150,000 bpd), Warri (built in 1978 with 125,000 bpd) and Kaduna (built in 1980 with 110,000 bpd). The main reason was that it became clear that the nation's demand for refined petroleum products was growing in leaps and bounds and there was a need to meet the ever growing market. In addition, studies by Nwogwugwu (2011) and Yusuf (2013) have shown that these conventional state owned refineries cost billions of dollar to build and millions of dollar to run and upgrade to keep up with the increasing demand for refined petroleum products in the country. These refineries were expected to process about 420,000 barrels per day of crude oil for domestic consumption if effectively functional and managed.

Nigeria needs to bridge the gap in the local demand for refined petroleum products. In view of this, it is necessary for the country to develop her refining potential (Sonibare *et al.,* 2007). It is therefore becoming imperative for the government to protect its oil refinery sector by engaging in policies that would boost refining capacity and utilization, reduce fuel scarcity, increase investment in the refining sector as well as increase internally generated revenue. One of the strategies developed in Nigeria to increase refining potential includes approval of more refineries (conventional and modular refineries) to complement the existing ailing four state-owned refineries (DPR, 2010; 2013). This study assessed modular refinery alternative as a strategic policy towards boosting local refining-capacity and capacity in Southwestern Nigeria.

Cenam Energy Partners (2014) define modular refinery as a petroleum refinery whose parts or equipment's are constructed in modules designed to be easily transported quickly and easily anywhere in the world.It comes in a variety of sizes with capacities that range from five hundred (500) barrels per day to one hundred thousand (100,000) barrels per day and are thus considered to be mini-refineries. The United States Energy Independent and Security Act (2007) define a small refinery (mini-refineries) as having less than seventy-five thousand (75,000) barrels per day in averagedaily crude oil throughput (Anthony *et al.*, 2014).

Igwe (2015) and Petroleum Trust Development Fund (PTDF) (2016) highlighted the need for Nigeria to establish modular refineries at strategic locations in the country. Among the reasons are: to improve the quantity of refined petroleum products supply, create more jobs, boost local content development and gain strategic energy security with the ability to refine crude oil locally. This is attributed to regarding refining-capacity and utilization as a strategic resource in energy poverty reduction and economic growth.In view of the above and continuous high demand of petroleum products for consumption in Nigeria due to increasing population and expanding transportation sector, but with low refining-capacity and utilization, there is a need for techno-economic assessment of modular refinery alternative in Southwestern Nigeria which could become part of a portfolio of domestic petroleum refining technology models in Nigeria.

Statement of the Research Problem

Nigeria's domestic refining industry capacity is inadequate to refine the crude-oil demand for development planning. Consequently, the modular refinery alternative has been advocated for adoption as a strategic option to boost the nation's refining capacity and utilization. However, there is a dearth of information on critical technological issues influencing modular refinery alternative establishment, its engineering economy viability and appropriate policy benchmark for modular refinery location in Southwestern Nigeria.

Aim and Objectives of the Study

The broad objective of this study is to assess the techno-economic viability of modular refinery alternative establishment in Southwestern Nigeria.

The specific objectives of the research are to:

(i) examine critical technological issues influencing the establishment of modular refinery alternative in Southwestern Nigeria;

(ii) assess engineering economy of MRA in (i); and

(iii) develop the appropriate policy benchmark for MRA location in Southwestern Nigeria.

Significance of the Study

This study has both theoretical and practical significance. The main significance of this study is to provide an understanding of the importance of the MRA and its positive contribution to increasing domestic refining-capacity and utilization and the development of economy of Nigeria.

LITERATURE REVIEW

The Petroleum Industry

The petroleum industry has been categorized into many segments by different scholars and schools of thought. Generally, the operations of the oil and gas industry are divided into two major activities; the Upstream and Downstream sectors. According to Fahim *et al.* (2010), the upstream activities include: geodetic survey; civil works such as site surveys and preparation of drilling locations; seismic data acquisition; drilling operations; geological activities; crude oil transportation and storage, and exploration and production; while activities in the downstream sector include: gas treatment; crude oil and gas conversion into refined and petrochemical products, transportation and distribution of refined products. Oyejide and Adewuyi (2011) in their view classified the oil and gas value chain into three major sectors; upstream, midstream, and downstream activities with transportation occupying the midpoint between upstream and downstream activities. In the same vein, Briggs *et al.* (2012) alluded that the petroleum industry's activities have traditionally been segregated into three segments, the upstream exploration and production (E&P) of crude oil, the midstream segment that transports crude oil and refined petroleum products (RPPs), and the downstream refining and marketing segments.

Petroleum refining processes

Refineries process different types of crude oil to make a broadly similar range of products (LPG, gasoline, and kerosene, gasoil/diesel and fuels oils).Refineries are different in terms of types of processing units, and relative and absolute size. Petroleum refining involves the separation of crude petroleum into fractions and subsequently treating these fractions to make petroleum products. This is illustrated by EIA (2013) which identified over hundred different plant configurations in 23 Member States. Parkash (2003) opines that the basic processes in the production of refined oil products from crude oil can be categorized in the following groups:

(i) Distillation processes: Theseare physical separation methods to decompose homogeneous liquid mixtures under usage of the different boiling behavior of the mixture components.

(ii) Conversion processes: These are chemical methods used to change the chemical structure of hydrocarbons contained in the different crude oil fractions.

(iii)Finishing processes of refined oil products: These are processes which entail removing compounds which hinder further processing or the quality of finished products.

(iv)Other processes: Besides these basic procedures mentioned above, a number of further procedures are necessary to achieve the desired quality of the oil products and process by-products such as Sulfur.

Arising from above, figure 1 shows a schematic flow diagram of a typical petroleum refinery that depicts the various unit processes and the flowchart of intermediate products streams that occur between the inlet crude oil feedstock and the final end products (Gary and Handwerk, 2001 and 2007). The diagram depicts only one of hundreds of different oil refinery processing systems.

Characteristics and Types ofRefineries

Refining begins with the distillation, or fractionation of crude oils into separate hydrocarbon groups (Aggour, 1992). The resultant products are directly related to the characteristics of the crude oil processed. Most distillation products are further converted into more usable products by changing the size and structure of the hydrocarbon molecules through cracking, reforming and other conversion processes. These converted products are then subjected to various treatments and separation processes such as hydro-treating and sweetening to remove undesirable constituents and improve product quality.

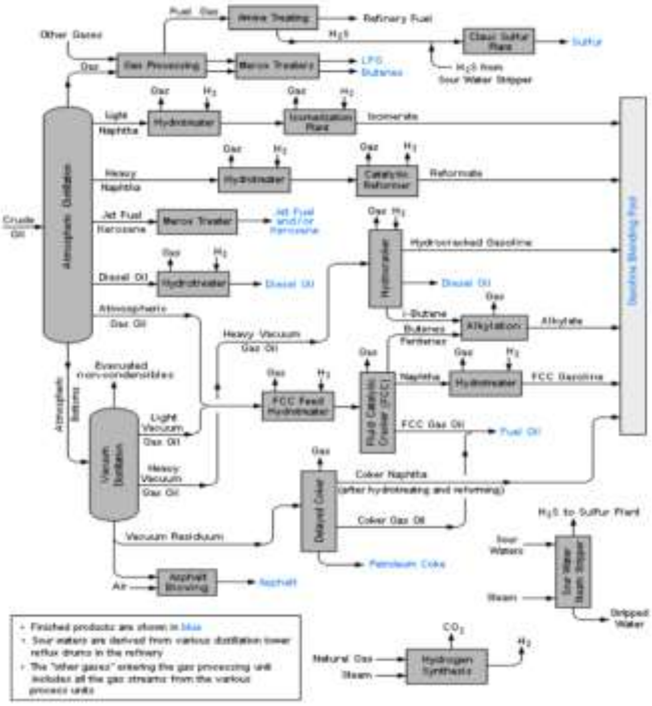

Figure 1: Simple Flow Diagram of a Typical Oil Refinery.
Source: Gary and Handwerk (2007)

Refinery configuration

The refinery configuration can range from single topping for crude distillation to a highly sophisticated conversion refinery. According to Dawe (2001), refinery configurations depend on several factors among which are:

(i) **Types of Products:** In this case, refining is carried out by increasing the hydrogen/carbon (H/C) ratio. This can be achieved either by hydrogenation processes such as hydro-treating, hydro-cracking or by carbon rejection processes such as thermal cracking (coking) and fluid catalytic cracking (FCC). Some products can also be produced by special refining operations, like in catalytic reforming, isomerization and alkylation.

(ii) **Environmental Regulation**: Modern regulations in many countries require a low level of contaminants like sulfur. This requires the change of severity or design of hydro-conversion units which can produce ultra-low sulphur products. Clean fuels are gaining great interest, and completely new refinery configurations are now being introduced to produce clean fuels from new refinery feeds and configurations. According to Babich and Moulijn, (2003), changes in refinery operation units are made in response to environmental regulation changes which affect modern refineries.

(iii) **Crude Assay and Quality:** Crude quality is getting heavier worldwide. Existing refineries, which are designed to handle normal crudes, are being modified to handle heavy crude. New technology for upgrading is used to obtain clean and light products from lower cost feeds. The crude assay will determine the yields of different cuts and consequently, the refinery configuration.

(iv) **Refinery-petrochemical Integration**: The growth of the petrochemical industry has put pressure on refineries to either change their configuration or operating conditions to produce more aromatics and gases. FCC has been developed to petro-FCC which produces high yield of gases. The phasing out of the idea of increasing the octane number by increasing aromatic content has changed the role of the catalytic reformer to produce a high yield of aromatics as BTX feedstock. The addition of gasification units to process vacuum residue has opened the way for the addition of a variety of petrochemicals.

(v) **Development of New Technology:** If a new technology is developed to give better yields, save energy, and meet environmental regulations and product specifications, then this technology might replace old technology in existing and new refineries, depending on the economics. Other factors, which might influence the refinery configuration, are feedstock availability, product markets and a company's strategic objectives among others.

Overview of oil refinery sector in Nigeria

In Nigeria, crude oil is produced mainly in the oil fields of the Niger Delta Region. The oil fields are characterized by multiple sand reservoirs of tertiary sedimentary deposits. Consequently, on the out fields the wells exist as pockets with each crude possessing a unique character (Ekweozo *et al.,* 1988). Presently, there are more than fourteen (14) commercially available crude oil blends in Nigeria. These include: Bonny light, Bonny medium Qua Iboe light, Escravos light, Brass Blend, Pennington light, Focados blends, Amenam blend, Oso condensate, Yoho light, Erha blend, Bonga blends and Agbami light (NNPC,2012). For the purpose of measurement uniformity, crude oil is measured in barrels (API, 2006). A barrel of crude oil is equal to 42 U.S. gallons, 35 imperial gallons or 159 litres (API, 2006; PPPRA, 2014). Agbon (2012) stated that there are 45 gallons of petroleum products in one barrel (42 U.S gallons) of crude oil, which consist of four gallons of liquefied petroleum gas (LPG), 19.5 gallons of gasoline, 10 gallons of diesel fuel, four gallons of aviation fuel, two-and-half gallons of fuel oil and five gallons of bottoms. Therefore, a barrel of refined petroleum products contains more gallons of PMS than any other petroleum products, making it the most important product.

Nigeria's state-owned refineries (Port Harcourt I and II, Warri, and Kaduna) have a combined nameplate capacity of 445,000 bpd, but problems such as sabotage, fire, poor management and lack of regular maintenance has contributed to low current refining capacity of around 214,000 bpd. Plans for several small, independently-owned refineries are also being considered in Nigerian. One of such is the 1,000 bpd Ogbele Diesel Plant refinery owned by Niger Delta Petroleum Company (NDPC) located in Bayelsa State (NNPC, 2013 and DPR, 2013). This type of refinery size and configuration is known as a modular refinery.

Concept of Modularity

Modularity which offers a very general set of principles for managing complexity, has become increasingly important because of the growing complexity of modern technology (Eager, 2010).The literature describes modularity as the process of building a complex product or process from smaller sub-systems that can be designed independently, yet functions together as a whole. Fixing and Mari (2001) alluded that the modularity concept then enables the scheme by which interfaces shared among components in a given product architecture become standardized and specific to allow for greater reusability and commonality sharing of components among product families.

Modular construction includes methods by which materials and/or prefabricated components are joined together off-site or on-site before being installed in their final position. Sturgeon (2002) has defined three levels of modular construction methods which include:

(i) **Prefabrication:** A manufacturing process, generally taking place at a specialized facility, in which various materials are joined together to form a component part of the final installation.

(ii) **Preassembly:** A process by which various materials, prefabricated components, and /or equipment are joined together at a location away from the final point of assembly for subsequent installation.

(iii)**Module**: A product resulting from a series of off-site assembly operations; it is usually the largest transportable unit or component of a facility.

Concept of modular refinery

A modular refinery is a refinery that is built in sections or modules so that it can be easily transported or relocated.Most mini-refineries are modular in design (Christensen, 1997; Schilling, 2000). A modular-based refinery structure consists of units that have the capability of processing 1000 and 70,000 barrels per day (bpd). Modularity in design can therefore be defined as choosing the design boundaries of a product and of its components, i.e. on how to divide a system into modules, so that the design features and tasks are interdependent within and independent across modules (Fixson and Mari, 2001). With supporting infrastructure such as storage tanks, a unit can take no less than a few weeks to be deployed. This is a vast departure from the conventional (traditional) refinery structure that takes years to build and be operational. Hence, the units for a particular mini-refinery (modular refinery) depends on the feedstock, desired products, desired product quality and availability of utilities. The uses of a mini - refinery are listed below:

(i) For research and development.
(ii) Test-run reconstruction of existing refinery.
(iii) Supply of refinery products to remote areas.
(iv) Supplement product supply from larger commercial refineries.

Concept of critical technology

Technologies represent the driving force in national economic prosperity and security and are regarded as critical to national interests (Stewen *et al.*, 1998). In other words, critical technologies mean technologies having a strong potential to influence national competitiveness and quality of life.

Critical technologies selection

Organizations must define what a critical technology is before determining which technologies are, in fact, critical technologies. Today, technologies are more sophisticated than ever before and as diverse. From defense weapons and satellite systems with embedded software to nuclear waste processing facilities, oil and petroleum systems, and highly distributed IT systems that operate on a national or global scale.

Critical technological issues in the oil refinery sector:

Investors need to understand the industry.The technical and economic implications of the project, the sociological and environmental impact of the plant, and maintenance provisions protecting the health of the operating staff and safety of the plant must be understood as well for investment decisions. This is to prevent avoidable waste of resources.

The Concept of Techno-Economic Assessment

A comparison of technology alternatives on a cost basis can be complex, but can be achieved on a straightforward analysis approach. Different technologies offer different data rates, and capacities among others. However, it is very important to investigate under which conditions, these different technologies are acceptable from an economical point of view. This calls for techno-economic evaluation. For the techno-economic evaluation, a methodology is defined, ranging from assumptions in economic calculations (Grant *et al.*, 1982).

Techno-economic framework

Techno-economic modeling evaluates technology investment options to assess the competitiveness of new alternatives as new eco-designs enter into service or new regulations come into force. The approach simulates new build and retrofit technology decisions using regulatory compliance, payback period, net present value (NPV), return on investment (ROI) and other key criteria.

The techno-economic methods emerged to study the economic impact of novel technologies and services realized with them. According to Bauer (2008), applying economic theory to engineering problems is challenging due to different goals and mindsets of economists and engineers. In this study, the term techno-economic analysis is used more broadly to encompass both qualitative and quantitative methods to analyze and to evaluate emerging technologies, and the applications and services based on them, from the viewpoints of various stakeholders, including developers, deplorers, and users of a new or old technology.

RESEARCH METHODOLOGY

Study Area

This study covered Southwestern Nigeria, which comprises Ekiti, Ondo, Ogun, Osun, Oyo and Lagos states. The choice of the study area was due to the increasing demand on the transportation sector and households in Southwestern Nigeria. This is due to sheer population and concentration of industrial and manufacturing activities in this region.

Population of the Study

The population of the study consists of energy industry experts involved in petroleum refining in Southwestern Nigeria from the following institutions/organizations:

(i) Academic institutions,
(ii) Commercial banks,
(iii) Government energy policy makers; and
(iv) Energy management advisory firms.

This is important because expert knowledge is a product of unique reasoning systems (Fazey *et al.*, 2005; Chi, 2006).According to Goodwin *et al.* (2006) experts with suitable backgrounds can be found in government, industrial trade associations, technical institutes, industry and universities. The goal of expert judgment may be choosing the proper methodology; the parameter value from ranges provided; the most appropriate activity data to use; the most appropriate way to apply a methodology; or determining the appropriate mix of technologies in use. Energy industry experts constituted the creative backbone of the study as the respondents.

Sample and sampling techniques

A purposive sampling technique was adopted to select the sample size for the study. The sampled population was the energy industry experts. The choice of thisset of respondents was on the basis of their high level of specialization and professionalism required in the petroleum refinery sector of the oil and gas industry. Sutherland (2006) and Kuhnert *et al.* (2010) assert that where empirical data are scarce or unavailable, expert knowledge is often regarded as the best or only source of information.

Methods of Data Collection/ Research Instruments

Data for this study were collected using both primary sources and interviews and secondary sources.

Sources of data

(i) Primary source: Primary data was collected through the administration of questionnaire and interviews. The questionnaire was structured and administered on the respondents and interviews wereconducted to corroborate the information on the questionnaire.

(ii) Secondary sources: The secondary data were obtained from the literature, such as oil and gas journals, petroleum engineering journals, textbooks, newspapers, magazines, the internet, published and unpublished research works and international reports.

Pilot survey

Prior to administering the questionnaire for final survey, a pre-test (pilot) survey should be conducted to gather information regarding potential improvements for the survey DeMaio *et al.* (1998) as cited by Behnke and Kelly (2011). The pre-test was conducted with 5 (17%) respondents of the target sample population, and respondent debriefing was used to correct the questionnaire for the survey.

Administration of Questionnaire

A purposive sampling method was adopted to select thirty (30) respondents for the study using one set of structured questionnaire. This study utilized Assessment of Technical and Economic Viability of Modular Refinery Questionnaire (ATEVMRQ). The questionnaire was administered to the purposefully selected respondents

Method of Data Analysis

A multiple analytical methods were used to analyze the data in this study. These include descriptive statistics, engineering economy process techniques and location analysis. The descriptive data analysis involved frequency, percentages and weighted average. For the variables that assessed the respondents' levels of importance on critical technological factors and location factors, a 5-item Likert scale was used to evaluate the weighted average (WA). This is also known as the mean value. Vukicevic *et al.*, (2010) states that the Weighted Average (WA) is expressed as:

$$WA = \Sigma \frac{FW}{N} \qquad \text{(i)}$$

Where;

F_i is the frequency of response

W_i is the weight or number assigned to the response on the Likert scale; and

N is the total number of response.

The use of mean to answer research questions by accepting or rejecting a statement has been widely employed by many researchers Johnson and Onwuegbuzie (2004). They opined that researchers should fix a mean cutoff point higher than the scale mean value for accepting the items otherwise reject.

Since the factors in the study were ranked on a 5-point Likert scale, the mean value or weighted average is 2.5. These criteria below were used as a cut off point for accepting or rejecting each of the ranked variables by the respondents. This idea was based on the assertion of Wright and London (2009) that researcher should fix a mean cut-off point higher than the scale mean value for accepting the items.

RESULTS AND DISCUSSION

Cumulative analysis of the proportional distributions of questionnaire byInstitutions/organizations

Table 1 presents the cumulative proportional distribution rates of 30 copies of questionnaire administered. An introductory letter was written to solicit the respondents' consent and participation in the study as well as stating the overall goal of the survey. Majority (15) of the copies of questionnaire were allocated to the academic institutions (Federal Universities). This was purposeful because there has been an increasing focus on the role that universities can play in contributing to economic growth. Also, universities have received increasing attention in innovation studies due to their importance as

Table 1: Cumulative analysis of the proportional distribution of questionnaire by institutions/organisations

Name of Institutions/ Organisation	Number of Questionnaire Administered	Percentage Questionnaire Administered
Academic Institutions	15	50.00
Commercial Banks	5	16.66
Government Energy Policy Makers	5	16.66
Energy Management Advisory Firms	5	16.66

catalysts for knowledge based growth and contributions to innovative performance (Jackson, 1999; Ojewale *et al.*, 2001; Dada, 2014). All the fifteen (100%) copies of questionnaires administered on theacademic institutions' were retrieved, and also all the five (100%) copies administered in energy management advisory firms' were retrieved.The results were expected because 50% of the respondents are in the academic institutions' and they will be willing to provide information on their research activities and conferences attended for their academic career development. The retrieval rates of 80% and 60% were from the commercial banks' and government energy policy makers respectively. The lowest rate (60%) was recorded from the Government energy policy makers, which may not be unconnected with the official secrecy and information confidentiality policy in government.

Table 2 presents the response rates relative to the total number of copies of questionnaire administered by categories of respondents. The utmost (55.5%) response rate was recorded for the academic institutions' comprising University of Ibadan (UI), Obafemi Awolowo University (OAU) and University of Lagos (UNILAG). This was followed by response rates of 14.8%, 11.2% and 18.5% for Commercial Banks (CBs), Government Energy Policy Makers (GEPM) and Energy Management Advisory Firms (EMAF) respectively. The response rates support van der Gaag *et al*., (1999) and Ayubb (2001) submission that experts respect and appreciate the efforts a researcher has put into developing the elicitation documentations and the questions, and are generally inclined to reciprocate by devoting similar time and effort when making their judgments.

Table 2: Proportional retrieval of questionnaire by institutions / organizations

Respondents' Characteristics	Respondents' categories	
	Frequency	Percentage
Institution/Organization		
UI	5	18.5
OAU	5	18.5
UNILAG	5	18.5
CBs	4	14.8
FMPR	3	11.2
GEPM	5	18.5
Total	27	100

Demographic and socio - economic characteristics of the respondents

Table 3 shows the results of demographic and socio-economic characteristics of the respondents from all the four (4) institutions/organistaions. Firstly, 7.4%, 18.5%, 48.2%, 14.8% and 11.1% of the respondents were in the age ranges of 21-30 years, 31-40 years, 41-50 years, 51-60 years and 61 years above respectively. Majority (74.1%) of the respondents sampled were in the age bracket of 21 years to 50 years, which showed that they are in their active service ages. Employees that are above the productive age are assumed not to have strength to engage in technical activities (Adeyemo, 2009).

Table 3: Demographic and socio- economic characteristics of respondents

S/N	Characteristics	Frequency	Percentage (%)
1	Age Range in years		
	21-30	2	7.4
	31-40	5	18.5
	41-50	13	48.2
	51-60	4	14.8
	61 Above	3	11.1
	Total	27	100
2	Marital status		
	Single	2	7.4
	Married	22	81.5
	Widowed	1	3.7
	Divorced	-	-
	Separated	-	-
	No Response	2	7.4
	Total	27	100
3	Highest Educational Qualification		
	HND	2	7.4
	B.Sc/ BA/ LL.B	6	22.2
	M.Sc/ MBA	5	18.5
	Ph.D	14	51.9
	Total	27	100
4	Academic specialization		
	Physical Science	5	18.5
	Engineering / Technology	11	40.8
	Social Sciences	4	14.8
	Management Science	4	14.8
	Humanities	2	7.4
	Law	1	3.7
	Total	27	100

This also indicates that most of the respondents were young and in their prime age in terms of total factor productivity.

Table 3 further shows that the lowest educational qualification of the respondents was first degree or its equivalent in addition with other professional qualifications. Specifically, 29.6%, 18.5%, and 51.9% of the respondents possessed HND/ B.Sc. /BA / LL.B; M.Sc/ MBA/ and Ph.D respectively. Majority (51.9%) of the respondents held Doctorate degrees. This may not be unconnected with the fact that respondents have improved their knowledge through additional education and training, making them professional and experts in the energy industry.

Distribution of respondents by highest educational qualifications

This knowledge increase would enable them gain experience by taking on new positions and additional responsibilities (Gosling and Mintzberg, 2004). The results of the highest educational qualifications and other professional qualifications therefore, affirmed the traditional theory of expertise knowledge that experts are trained appropriately, and then slowly accumulate knowledge over long periods of time through experience (Basadur *et al.*, 2000).

Distribution of respondents by academic specialization

Table 3 shows that most (59.3%) of the respondents' academic specialization (background) were in the physical sciences, engineering and technology. Ajeyalemi (1987) and Ogunleye (1999) have argued that Science subjects have a significant impact on the technical service sector. The results from the survey of academic specialization support this argument. This result shows importance of technical professional over the total number of other academic background in the energy industry. About 41% of the respondents had their background in social sciences, management sciences and humanities and law. The least (11.1%) group of respondents had humanities and law as their academic background.

Distribution of respondents by professional bodies

As presented in Table 4, approximately 88.9% of the respondents belonged to a professional association. Only 16(51.8%), 3(11.1%), 3(11.1%), 2(7.4%) and 3(14.8%) of these categories of respondents are members of Council of Registered Engineers of Nigeria (COREN)/ Nigerian Society of Engineers (NSE); Nigerian Institute of Management (NIM); Institute of Chartered Accountants of Nigeria (ICAN); and Nigeria Economic Society (NES) respectively. The academic institution has the highest memberships in the professional bodies and supports the result that in addition to the important core missions of research and teaching, there are other multifaceted roles that universities play in stimulating innovation and economic growth.This implies that the respondents may have acquired more knowledge and experience through attending conferences and workshops. About 60% of members of the professional bodies are mainly in the physical sciences, engineering and technology academic background. This means science and technology (S&T) policy in Nigeria must be enhanced for the sustainability of the energy industry.

Table 4: Characteristics of respondents' Professional Qualification(s)

Characteristics	Frequency	Percentage
Professional Qualification		
Council for the Regulation of Engineering in Nigeria/ Nigeria Society of Engineers COREN/NSE	16	59.3
Nigerian Institute of Management (NIM)	3	11.1
Institute of Chartered Accountant of Nigeria (ICAN)	3	11.1
Nigeria Economic Society (NES)	2	7.4
No Response	3	11.1
Total	27	100
NBA*	10	

NBA*: Nigeria Bar Association

Distribution of respondents by working status

Table 5 shows that 77.8%, 7.4%, 11.1% and 3.7 % of the respondents were in permanent, temporary, contract and consultancy employment respectively. The result of highest (77.8%) dominance of permanent employment affirmed International Labour Organisation (ILO) conventions on labour employment (ILO and WTO, 2000). Majority (63.3%) of the respondents had between 11-30 years of working experience (Table 4.5). Moreover, the results show that 18.5%, 29.6%, 33.3%, and 18.5% had spent between 1-10 years, 11-20 years, 21-30 years and 31- 40 years respectively in their different positions within their respective institutions / organizations. The cumulative results indicated that 81.4% had over 10 years of working experience in the energy industry. This long period of working experience in the energy industry by the respondents may indeed represent a situation where expert knowledge is often regarded as the best or only source of information (Sutherland 2006; Kuhnert *et al.*, 2010). It was argued further that the period of practice to be an expert is typically no less than around ten years for most experts.

Table 5: Characteristics of respondents by type of employment and experience

Characteristics	Frequency	Percentage
Type of Employment		
Temporary	21	77.8
Consultancy	2	7.4
Contract	1	3.7
Total	27	100
Years of working experience of Respondents		
1-10	5	18.5
11-20	8	29.6
21-30	9	33.3
31-40	5	18.5
Total	27	100

Critical Technological Issues influencing Modular Refinery Alternative (MRA) in Southwestern Nigeria.

This section addressed the first objective of the study. Respondents ranked the relative importance of identifying fifteen (15) critical technological factors influencing modular refinery alternative in Southwestern Nigeria with results summarized in Table 6. The factors are listed (numbered from 1 to 15) in the first column of the table. Column two lists against each factor the frequency distribution of responses on a 5-point Likert scale. The results showed that twenty seven (100%) respondents ranked only each of these nine (60%) critical technological factors; refinery configuration, crude oil input characteristics, refiners /investor's margin, bankable loan facility; storage capacity; product quality; refinery yield; government incentives and production planning 'Extremely Important'.

The other six (40%) critical technological factors are: refinery size, capacity utilization, camera surveillance, worker protective equipment, energy efficiency and refinery facility management. Twenty five (92.6%) respondents ranked each of the six critical technological factors 'Extremely Important' and the remaining two (7.4%) respondents ranked each 'Very Important'. The results of descriptive analysis showed that all the respondents ranked the critical technological factors influencing modular refinery alternative in the Southwestern Nigeria 'Extremely Important'.

Table 6 also shows the computed weighted average (WA) of the fifteen (15) critical technological factors influencing modular refinery alternative in Southwestern Nigeria. The computed weighted average revealed refinery configuration was ranked extremely important with a weighted average of 5.0 out of 5.0 maximum. This result is 'very significant' based on the scale adopted in the study. The result was expected; selection of refinery configuration optimum for processing crude oil and getting desired products slatequality will be key to sustainability (Gary and Handiwerk, 1984; 2001). The results could be attributed to the fact that a refinery process configuration is a blueprint and a basis for economic study and decision making that would be meeting the production and economic objectives of a particular refinery operation. The type of crude oil that a refinery is able to process is determined by the refinery configuration. This result is in line with Jacobs's consultancy (2012) that the High-Conversion US Gulf Coast refinery configuration makes much more gasoline than the other refinery configurations. This result shows the importance of refinery configurations in determine future profitability of petroleum refining operation.

Crude oil input characteristics have also been with a weighted average of 5.0. This result is 'very significant' based on the scale adopted in the study. The result was expected The basic choice of which crude to refine is between lighter and heavier grades and each grade of crude yields a different array of refined products, each of which has a different price that also varies by regions (Oil and Gas Journal, 2013b).

Table 6: Critical technological factors influencing the establishment of modu1arrefinery alternative in Southwestern Nigeria

Factors	Rating in Frequency and Percentage					WA
	I	ii	iii	iv	V	
Refinery size				2 (7.4%)	25(92.6%)	4.9
Refinery configuration				-	27(100%)	5.0
Capacity Utilisation				2 (7.4%)	25(92.6%)	4.9
Crude oil input characteristics				-	27(100%)	5.0
Camera Surveillance				2 (7.4%)	25(92.6%)	4.9
Refiners / investors margin				-	27(100%)	5.0
Workers protective equipment				2 (7.4%)	25(92.6%)	4.9
Energy efficiency				2 (7.4%)	25(92.6%)	4.9
Refinery facility management				2 (7.4%)	25(92.6%)	4.9
Bankable loan facility				-	27(100%)	5.0
Storage capacity				-	27(100%)	5.0
Products quality				-	27(100%)	5.0
Refinery yields				-	27(100%)	5.0
Production planning				-	27(100%)	5.0

KEY: (i) Neutral (ii) Not important at all (iii) Slightly important (iv) Very important (v) Extremely important Weighted Average **(WA)***

Refiners/ investors margin was weighted 5.0, this was also 'very significant' based on the study's adopted weighted average classifications. The result could be attributed to the apparent refinery profitability being generally related to multiple markets: supply of crude oil, demand for light products, and demand for heavy products. In general, refining margins rise when oil products demand is strong and supply of oil is relatively abundant, and drop if demand is weak and supply is constrained.

Storage capacity and production planning were ranked extremely important by all (100%) respondents with each average index of 5.0 out of maximum of 5.0. Each of the results is 'very significant' based on the study's weighted average classifications. These results were also expected.The crude oil feed and the processed products are stored in storage tanks of various sizes and types located together in the refinery area usually known as a Tank Farm (Jones and Pujado, 2005). Also, storage capacity, which exists at every point in the supply chain is important because stocks can be used to help reduce the magnitude of sharp price spikes due to physical disruptions to supply (Bacon and Kojima, 2008). Kojima *et al.* (2010) attributed the functional storage capacity activity to coordination of procurement and transport logistics, including considerations of volumes required, procurement methods, price, location, contracting terms, and supply reliability.

Production planning is an important requirement in planning the refinery's daily and long term operation. Production planning enables refineries of a company to develop their own operating program. This may be attributed to production planning as an essential tool in today's petroleum refining industry. It aids in decision making and resource allocation to achieve business objectives through optimal production, distribution, sales and inventory management (Grossmann, 2005).

Product quality with the average weight of 5.0 was 'very significant' based on the average weighted index classification adopted for the study. The result could be seen from the perceived respondents that the petroleum refining industry provides products that are critical to the functioning of the economy. The technology of the refinery must conform to both the product yields and environmental regulations. Refinery yields were also ranked extremely important with an average index of 5.0. This result is also 'very significant' based on the study's weighted average classifications. This result could be attributed to the apparent fact that different types of refineries and different crudes would produce different product yields. A typical product yield or a refinery's product slate, and the proportion of refined products obtained by refining one barrel of crude are different (API, 1993). This yield reflects both the refinery's configuration and, because all crude oils differ in their hydrocarbon composition, and the type of crude oil that is processed.

Government incentives were perceived extremely important by the respondents with a weighted average of 5.0. The result was 'very significant'. This result could be attributed to the importance of the refining industry cum environmental standards and regulation which may be a barrier to entry into the market. The investor may like to see a smooth, timely permitting process in which administrative delays are minimized and industry would also prefer to have flexibility in how, technologically to meet environmental standards. This may also be because refiners need such support due to lower margins for mini-refineries (due to lack of economies of scale). Small refineries do face many of the same economic, market, and environmental factors that affect large refineries but may be saved through government incentives.

The bank loan facility was ranked by the twenty-seven (100%) respondents extremely important with an average index of 5.0. This is also 'very significant' based on the study weighted average index classifications. This result supports Herrman *et al.,* (2010) observation that petroleum refining is capital-intensive. Also, because refining is caught between the volatile market segments of cost and price, it is exposed to significant risks as the refinery business needs huge investment. Oil & Gas Journal (2013b) assert that a refinery will close if it cannot sustain its profitability.

Refinery size ranks by 92.6% and 7.4% respondents as extremely important and very important respectively with a weighted average of 4.9. The result is very significant based on the classification of the weighted averaged index ranking adopted for the study. The outcome of the study could be attributed to the assertion of Piorg (2005) that evaluating the economic performance of the petroleum refining industry is complicated by the fact that many refineries can use crude oil of different quality as an input, while others cannot. This is mainly because of the differences in refinery sizes as well as the strategy of the refinery and the desired products to be produced.

Workers protective equipment was ranked by 92.6% and 7.4% respondents as extremely important and very important respectively with a weighted average of 4.9. The result is very significant based on the classification of the weighted averaged index ranking adopted for the study. This outcome could be attributed to the fact that several hazards may occur in any oil refinery such as fire, hazardous chemicals, etc. It is important to consider putting in safety policy of workers in the refinery industry. Also, energy efficiency ranks by 92.6% and 7.4% respondents as extremely important and very important respectively with a weighted average of 4.9. This is also 'very significant' based on the study weighted average index classifications. The result could be attributed to the fact that methods to improve energy efficiency are always needed.

RESULTS AND DISCUSSION

The net present value (NPV) analysis is adopted to determine the overall financial performance of the project (John, 2004). The NPV of the project was calculated from derived total discounted expenditure and income. The costs and revenues were calculated on an annual time-step with annuity held constant. Simple net present value analysis is adopted to determine the economic value of these hypothetical modular refinery projects. The projects are all assumed to reach economic limit at the end of year 22.

Table 7 shows the cumulative cash flows for the three mutually exclusive hypothetical modular refinery alternatives in Southwestern Nigeria. The 20,000, 40,000 and 60,000 barrels per day plant refineries options would each return the whole invested capital in the fourteenth (14th), ninth (ninth) and eighth years (eighth) of operation respectively.This is another critical and attractive issue. Table 7 presents results of the return on investment for the three hypothetical mutually exclusive modular refinery alternatives. The 20,000, 40,000 and 60,000 barrels per day plant refinery options have ROI of 8.5%, 37.2% and 37.3% respectively.

The results showed that the 60,000 barrels per day plant refinery size incurred the highest investment cost but have the highest NPV ($60.82M), earliest breakeven point at the eighth year and highest ROI (37.3%). Hence, the 60,000 bpd modular refinery plant size is considered as the most economically and desirable in Southwestern Nigeria.

Environmental factors were ranked extremely important by 92.6% and very important by 7.4% of the respondents with a weighted average of 4.9 out of maximum of 5.0. This result is very significant. Accidental oil spills pollute the groundwater and open ways. Sonibare *et al*. (2007) support this view, noting that oil refineries also cause smog, air pollution and other hazardous by products. Infrastructure is also of major concern in MRA location decisions. Infrastructure proximity was ranked extremely important by 92.6% and very important by 7.4% of the respondents with a weighted average of 4.9 out of maximum of 5.0. This result is also very significant. Flaig (1993) opined that the existence, quality and reliability of modes of transportation, the quality and reliability of utilities and telecommunication systems have been highlighted as very germane in other studies.

Table 7: Comparative cumulative cash flow for the three hypothetical mutually exclusive modular refinery alternatives in Southwestern Nigeria

End of Year	**Net Present Values (NPV) $M**		
	20,000 bpd	**40,000 bpd**	**60,000 bpd**
0	-10	-18	-23
1	-43.33	-68	-106.33
2	-57.57	-87.44	-129.19
3	-46.75	-65.8	-96.73
4	-37.7	-47.77	-69.69
5	-30.21	-32.74	-47.15
6	-23.95	-20.22	-28.37
7	-18.73	-9.78	-12.72
8	-14.38	-1.08	0.32
9	-10.76	6.17	11.19
10	-7.74	12.21	20.25
11	-5.22	17.24	27.8
12	-3.12	21.43	34.09
13	-1.37	24.92	39.33
14	0.09	27.83	43.7
15	1.3	30.26	47.34
16	2.31	32.28	50.37
17	3.15	33.97	52.9
18	3.85	35.37	55.01
19	4.44	36.54	56.77
20	4.93	37.52	58.23
21	5.34	38.33	59.45
22	5.96	39.48	60.82
	NPV = 5.96	39.48	60.82

Table 8: Return on investment (ROI) for each of the three hypothetical mutually exclusive modular refinery alternatives in Nigeria

Refinery size	20,000 bpd	40,000 bpd	60,000 bpd
ROI	8.5%	37.2%	37.3%

Development of appropriate policy benchmark for MRA location in Southwestern Nigeria
Table 9 presents the results of the identified influencing location factors for MRA in Southwestern Nigeria. The respondents ranked each factor on a 5 point Likert scale (least (1) to highest (5).

Table 9: Facility location factors for MRA location in Southwestern Nigeria

Factors	Rating in Frequency and Percentage					WA
	I	ii	iii	iv	v	
Government and political	-	-	-	-	27(100%)	5.0
Security	-	-	-	-	27(100%)	5.0
Environmenta	-	-	-	2 (7.4%)	25(92.6%)	4.9
Economic	-	-	-	-	27(100%)	5.0
Infrastructure	-	-	-	2 (7.4%)	25(92.6%)	4.9
Availability of land	-	-	-	-	27(100%)	5.0
Labour Characteristic	-	-	-	-	27(100%)	5.0
Demand forecast	-	-	-	-	27(100%)	5.0

KEY: (i) – Neutral, (ii)– Not important at all, (iii) – Slightly important, (iv) – Very important and (v) –Extremely important.

Table 10 depicts the calculated distances in kilometers from Warri the source of crude oil to each state capital. State capitals were chosen for uniformity as a location site. The distances were calculated for; Ekiti, Ondo, Osun, Oyo, Lagos and Ogun as 309.98 km, 274.93km 388.70 km, 408.46 km, 424.51 km and 425.23 km respectively. The results of the calculated distances in kilometers from the Warri (source of crude oil) to the each states capital is in consonance with transport costs and barriers measurement that most of the research on gravity equations uses measurements of physical land and sea distances between national economic centers to proxy transport costs. The study determined Ondo state as the most appropriate location for the MRA. This is due to its close proximity to the source of crude oil. The results are in line with refineries tending to be located close to their feedstock for refined products.
Table 11 presents the results of the dimensional analysis used to determine the MRA location in Southwestern Nigeria. Raw material costs and transport ($M) and other utilities ($M) variables are in one dimension based on assumptions presented in chapter three. According to Palander (1935) the adopted theory of industrial location analysis indicated that costs of production were the chief determinants of location of industry. This is also known as the Least-cost Locational Approach. The results show Ondo state as having the least cost of production ($380.5M) among the six states under the study. Ondo state and its environs in Southwestern Nigeria account for a huge percentage of total national petroleum products consumption. The reason can be inferred from both the concentration of industrial and manufacturing activities in these regions and their sheer population. This result is in line with Arauzo and Josep (2005) whoreported that both factor-proportion differences and a proximity-concentration trade-off should be taken in to consideration so that firms can make the decision whether to invest or not.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary
The persistent low refining capacity and capacity utilization of the Nigeria's state owned four refineries and the reliance on imported refined petroleum products to meet domestic consumption needs led to the search for alternative ways of bringing efficiency in the petroleum refinery sector.The study assessed techno-economic viability of modular refinery alternative in Southwestern Nigeria. The studyidentified critical technological factors influencing modular refinery alternative in Southwestern Nigeria. It also assessed the engineering economy viability, as well as developed the appropriate policy benchmark for its location. This was with a view to boost Nigeria's refinery capacity and capacity utilization towards reducing refines petroleum products importation.

Table 10: State by State Analysis of the Calculated Distance by road from the Crude Oil source to the state capitals of each state of the Study Area

S/N	Source of Crude Oil	Usage Centre State Capital	Road Distance	Latitude (°N)	Longitude (o E)
1	Warri	Ekiti (Ado-Ekiti)	309.98	7.6656	5.3103
2	Warri	Lagos (Ikeja)	425.23	6.4531	3.3958
3	Warri	Ogun (Abeokuta)	424.51	6.9098	3.2584
4	Warri	Ondo (Akure)	274.93	7.0887	4.8388
5	Warri	Osun (Osogbo)	388.7	7.5876	4.5624
6	Warri	Oyo (Ibadan)	408.46	7.8372	3.9347

Table 11: Results of dimensional analysis used to determine the MRA location in Southwestern Nigeria

Factors	Ekiti	Lagos	Ogun	Ondo	Osun	Oyo
Raw material Cost and transport ($M	372.0	513.0	500.2	330.5	466.4	490.2
Other Utilities ($M)	55	65	55	50	50	52
Total ($M)	427.0	578.0	555.2	380.5	516.4	542.2

The study revealed insight on modular refinery alternative as high-tech venture and needs understanding of its technical and economic feasibility. The study showed that the identified critical technological factors influencing modular refinery alternative in Southwestern Nigeria were ranked extremely important by majority of the respondents who are energy industry experts and knowledgeable in the oil refining sector. These identified and examined critical technological factors are: refinery configuration, crude oil inputs characteristic, refinery facility management, environmental issues, products quality, refiners' /investors' margin and bankable loan facility. It was observed during the oral interviews that the majority of the respondents were hesistant to provide in-depth practical information on refinery planning and project cost. They attributed providing this informationas consultancy services and should attract remuneration.

Moreover, the study showed the results of the engineering economy assessment of the three hypothetical modular refinery alternatives. The study concluded that the 20,000, 40,000 and 60,000 barrels per day modular refinery alternatives plant sizes are all technically and economically viable in Southwestern Nigeria. This is because each refinery plant size has a positive Net Present Value (NPV) of $5.96M, $39.48M and $60.82M respectively at 20% interest rate (capital cost). The study also showed that all the identified locational factors for modular refinery alternative in Southwestern Nigeria were very significant and with a weighted average of 5.0. The study determined Ondo state as the most appropriate location for the establishment of modular refinery alternative in Southwestern Nigeria. This is due to its closest proximity to the source of crude oil (oil field) and had the least costs transportation cost and other utilities costs.

For all these above reasons, the study concludes and recommend for adoption,modular refinery in Southwestern Nigeria, it would enhance oil security and make economic sense.

Policy Recommendations

Policies and regulations are very important for the ultimate decision. Following the findings and conclusion of the study, the following policy recommendations were made:

(i) The identified critical technological factors are very significant and should beincorporated into the technical and economic structures of the possible adoption of a modular refinery to take advantage of latest petroleum refinery technology for optimal crude oil products slate.

(ii) The Federal Government of Nigeria should set up petroleum refinery bank tooffer specialized services such as refinery project management, refinery feasibility study, provision of loans and advances to modular refiners in concessionary terms. .

(iii) Governments would have to step in and control prices to make the petroleum refining profitable.

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