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Economic Analysis of Gas Pipeline Projects in Nigeria

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Abstract
Nigeria has the largest gas reserves in Africa and Gas pipeline industry has been in operation in the country since the gas discovery in the country in late 1960s. Lack of sufficient gas development infrastructure has caused energy imbalance in the country, and making the country rely heavily on the few existing pipelines, which makes the country's energy sector vulnerable to any shock on these pipelines. Recently, the Nigerian government resolved to build new gas pipelines as part of its plan to maximise gas utilization. As such, this research analysed the economics of these possible gas pipelines options so as to assess if investment in new gas pipelines is viable in Nigeria and which of the pipeline route option is more viable. The research used gas pipeline models that already exist in literature to analyse the investment cost, gas deliveries as well as costs and benefits of six possible gas pipeline routes options in the country. The BSRO pipelines route option was found to be more viable and estimated to have an annual gas delivery of 37.25 bcm, investment cost of $1.15 billion, NPV of $2.43 billion, IRR of 50.38%, payback period of 2.60 years for forty years of operation. However, in terms of coverage and ability to supply more gas to more locations, the all gas pipeline route option is more recommendable. Other gas pipeline routes options are also viable except the NRO gas pipelines, and it is recommended not to consider this option alone, even in the future, the best recommendation is to combine it with the BRO pipelines option.
Keywords: Gas Pipeline Routes, BNRO, BSRO, BNRO, NRO, SRO, NRO, NPV, IRR, payback period

List of Abbreviation
BRO: Base Route Option
BCM: Billion Cubic Metres
BNRO: BRO+NRO
BSRO: BRO+SRO
E (CCMS): Estimated Cost of Compressor Stations
E (CCP): Expected Cost of Constructing Pipeline
BWRO: First Alternative System
HP: Horsepower
IEA: International Energy Agency
IIC: Initial Investment costs
IRR: Internal Rate of Return
KM: Kilometre
LC: Labour Cost
MCM: Million cubic metres
IEA: International Energy Agency
NPV: Net Present Value
N: Nigerian Naira
NRO: Northern Route Option
NR: Not recoverable
PCW: Pipe Coating and Wrapping
PMC: Pipe Material Costs
SV: Salvage Value
SLD: Straight Line Depreciation
WACC: Weighted Average Cost of Capital

1. Introduction
It was reported that the domination of oil and gas resources in total energy mix will continue up to 2040 in Africa as reported in the IEA Africa Energy outlook, due to the slow growth of their potential replacements and/or alternatives [2]. However, the span of global proven conventional gas reserves was estimated to be around 54.1 years and that of oil around 52.53 years in 2014 by British Petroleum (BP) [3]. Accounting for recent discoveries of the Shale oil and gas reserves, the future longevity and domination of the oil and gas might be

extended [4]. With the fear of oil production peaking and its higher CO_2 emission than natural gas, the natural gas may take the lead and become more favourable in the future. Though, natural gas has long been dumped (or flared) due to the abundance and relative low cost of oil production. With the promising future for the natural gas especially in developing countries, where the demand for natural gas is very low, different sorts of natural gas uses can be developed to trigger its demand [5] [6].

Nigeria, being the most populous country in Africa and having the largest gas reserves in the continent, the need to invest and diversify the use of natural gas in imperative [7]. It was estimated that, by the year 2040, around 50 million people will still live without access to electricity [2]. Ibitoye (2007) estimated that electricity supply from gas will continue to dominate energy supply mix and will constitute 70% of the total electricity generation in Nigeria by 2030 [8]. Going by this estimate, we will witness additional 7% increase in the share of sources of electricity from natural gas in 2030 from 2011. IEA (2014) estimated that natural gas will dominate the future energy balance with 23% in 2040, which higher than 18% for oil and 5% for coal. Hydro and bioenergy were estimated to have a share of 2% and 50% respectively in 2040 [2].

The total final energy consumption in Nigeria as at 2012 was 121 Million tons of oil equivalent (Mtoe), which will increase by 64% in year 2040. This signifies significant increase in energy demand in the country in the future, which justifies the need for more investment and diversification of energy sources in the country. Lack of sufficient gas development infrastructure has caused energy imbalance in the country, and making the country rely heavily on the few existing pipelines, which makes the country's energy sector vulnerable to any shock on these pipelines. This is the reason why the Nigerian government developed a gas master plan, that enumerate intended investment projects that will help in diversify gas supply options, which will stimulate development of natural gas in the country to become the major energy source in the country [9] [1] [10]. Therefore, this research is aimed to provide economic framework of the key gas development project i.e. gas pipeline that can be implemented to achieve the objective of the plan. The research will also serve as an academic guide toward actualizing and extending the objective of the plan in the country.

Considering the large gas reserves and the persistent gas flaring in the country, the research is motivated to identify the gas development projects that can be implemented to use gas as a means of improving access to energy and making the gas reserves useful for the economic growth in the country. The research is motivated by the need to have estimation of the viability of these gas development projects so that investors would understand the viability of these gas development projects, which could motivate them to invest in the country. The research is also motivated by the need to have recommendation on the optimal and viable projects, and the need to provide recommendations for incentives to encourage investment in other non-viable projects in the country (if any).

In line with achieving the objective of the gas master plan in Nigeria of sufficient domestic gas supply, the research identified that gas pipelines are major and significant infrastructure necessary to utilizing the natural gas [11], and this is clearly outlined in the gas master plan. The research then asks: What are the optimal combination of the proposed gas pipeline route options? And what are the costs and benefits of each of the gas pipelines route combinations? This will help inform the government and prospective investors on the best combination of the gas pipeline route options, and the resulting costs and benefits of each of the gas pipelines routes so as to make optimal, informed and reliable investment decisions.

The research aims to identify and analyse the economics of the relevant gas development project (Gas Pipelines) that can help enhance domestic gas consumption. In other word, the aim of this research is to identify the different gas pipeline route options and analyse the economics of each of the options so as to stimulate latent demand for natural gas in the country in line with achieving the objective of the gas master plan of eliminating gas flaring and expanding domestic gas utilization in the country.

The objective of the research is to analyse the capital investment requirements for six different possible gas pipeline routes as well as their respective costs and benefits .An assessment will be carried out between these gas pipeline options in terms of its capital cost requirement, potential of gas delivery, and returns on investments. The research will use the NPV, IRR, Payback period and investment cost models already established in the literature to analyse the costs and benefits of the gas pipeline projects. Gas pipeline investment cost models as identified in Shahi (2013) will be used to estimate the Nigerian-specific capital cost requirements and gas delivery of the proposed gas pipeline routes [12].

The research is significant as it will analyse the key possible gas pipeline projects that Nigeria can develop to improve domestic gas utilization so as to reduce gas flaring, improve electricity generation, improve welfare of the people, facilitate more job opportunities, enhance productivity and efficiency in the productive sectors of the economy. As the research will provide empirical and analytical analysis of these gas development projects, it will serve as viability indicative framework of these projects for government and prospective investors in the gas sector in the country. The research will serve as the academic supporting document to the Nigerian gas master plan, as it aims to further provide economic assessment of gas development projects aimed at achieving domestic gas consumption as outlined in the plan. It serves as academic guide toward actualising the objective of the master plan

As the research is motivated to use natural gas to foster economic growth, it is significant as its finding will help in motivating and facilitating optimal gas development investments that are capable of creating gas consumption in residential, commercial and transport sectors of the economy, diversifying the economy and reducing the overall emission in the country. The research is significant as it informs the government and prospective investors on the best combination of the gas pipeline route options, and the resulting costs and benefits of each of the gas pipelines routes so as to make informed and reliable investment decisions.

This research analyses the economic costs and benefits of gas development projects in Nigeria. First, the chapter analysed the costs and benefits of the proposed gas pipeline routes in Nigeria, comparing the NPV, IRR, Payback period, gas delivery and initial investment costs of six different gas pipeline route combination options, with a view to recommend the optimal routes combination. Every methodology used is followed by relevant assumptions, data, results and discussions at the same time.

2. Gas pipelines in Nigeria

Gas pipeline industry has been in operation in Nigeria since the gas discovery in the country in late 1960s, but with a small supply of gas to few power stations. Recently, the Nigerian government is resolved to expand some of the existing gas pipelines in the country. Details of the proposed gas pipelines are contained in the Nigerian gas master plan[13] [14]. This is evidenced by the recent contract signed to build gas pipeline networks with a combined 30 billion cubic metres capacity per year with a diameter of 48 to 56 inches by Nigeria and Algeria [15] [16]. One of these pipelines is the Tran-Sahara gas pipeline initiated to provide route for the Nigerian stranded natural gas to Algeria, which will serve as a transit country to some European countries.

The pipeline will be connected to the "Trans-Mediterranean, Maghreb–Europe, Medgaz and Galsi pipelines" which will supply the Gas to the European countries. "The length of the pipeline would be 4,128 kilometres: 1,037 kilometres in Nigeria, 841 kilometres in Niger, and 2,310 kilometres in Algeria"[15], the pipeline is presented in figure 2.1 below. The trans-Sahara gas pipeline is an extension of the proposed south to north (trans-Nigeria) gas pipeline, which extended the Ajaokuta gas pipeline to Kano. The south to north gas pipeline is 56 inches and 48 inches diameter pipelines, from Calabar to Ajaokuta (of 490 kilometres) and from Ajaokuta to Kaduna (of 495 kilometres) respectively [1] [16]. Adding the distance from the Niger Delta gas-producing region to Ajaokuta, the trans-Nigeria gas pipeline (south-north pipeline only) will have a distance of 985 kilometres. This is also part of the Nigerian gas master plan[17], in addition, the other connecting pipelines like the Escravos gas pipeline extension made up of different inches will cover around 686 kilometres [10], and the interconnector gas pipeline, which is 100 kilometres long and 42 inches in diameter. The eastern and north gas pipeline extensions are potential future plan [18].

The business interest of the trans-Sahara pipeline will be 45% for Nigeria, 45% for Algeria and 10% for Niger republic. It was estimated to cost around $13 billion [19], and the trans-Nigerian was estimated to cost more than $2 billion with debt and equity ratio of 60:40[16]. Recently, there were lots of interest from some European countries to contribute in the gas pipeline construction, but the major players are mainly looking for who will add to the technical efficiency and improvement that will help reduce the cost without compromising the capacity. The trans-Nigerian pipeline is the immediate big gas development project that will be implemented soon and the engineering design is billed to start in early 2015. Figure 1 illustrates the general overview of the trans-Nigeria and trans-Sahara gas pipeline.

Figure 1: Tran-Sahara Gas Pipeline System[18]

The red line is the extended trans-Sahara gas pipeline up to Algeria, with other extension to European countries. The proposed networks of trans-Nigeria gas pipeline expansions are shown in figure 2 below [1] [19].

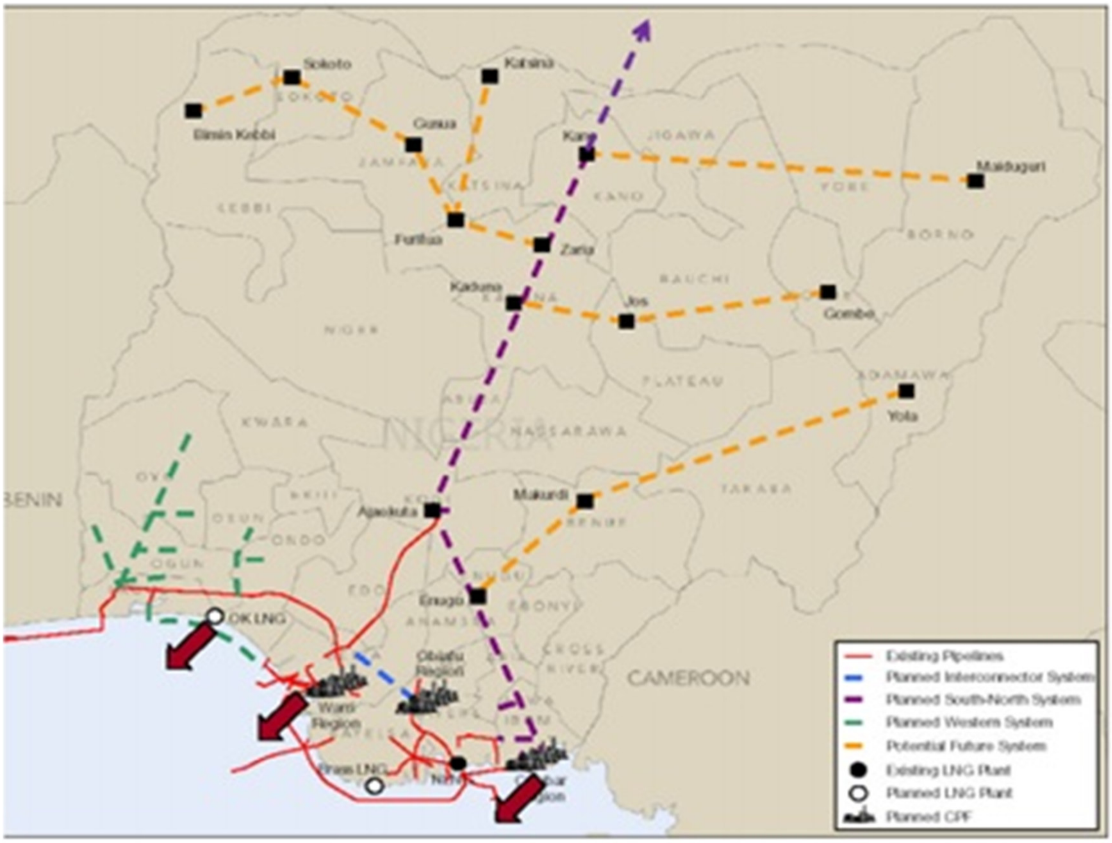

Figure 2: Proposed and existing gas pipelines in Nigeria [1]

From figure 2, the purple line is the proposed Trans-Nigerian, the yellow lines are the future extensions, the blue line is the proposed interconnector and the green lines are the proposed south-western extensions. The red lines are the existing lines. The only operating cross-border gas pipeline from Nigeria is the West African gas pipeline, which runs across some of the West African countries (Nigeria, Benin, Togo, and Ghana). The aim of the gas pipeline is to deliver purified natural gas to Ghana, which will be mainly be used for power generation and for industrial use. The pipeline links to the Nigerian Escravos-Lagos pipeline then pass through the coastal region (offshore). According to the West African Gas Pipeline Company (WAPco) the main pipeline is 20 inches in diameter, while Benin (Cotonou) and Togo (Lome) pipelines are 8 inches each, and the Ghana (Takoradi) pipeline is 18 inches in diameter. "The Escravos-Lagos pipeline system has a capacity of 800 mscfd, and the WAPCo system will initially carry a volume of 170mscfd and peak over time at a capacity of 460mscfd"[20] [21]. According to the company, the benefit is enormous, as it will reduce the cost of acquiring the natural gas for the West African Countries and ensure efficient supply of the cleanest fossil fuel. The project will serve as a foundation for further international investment; it will help in improving power supply and industrial growth in the region. It was estimated to cost $974 million [17]. The West African gas pipeline is illustrated in figure 3.

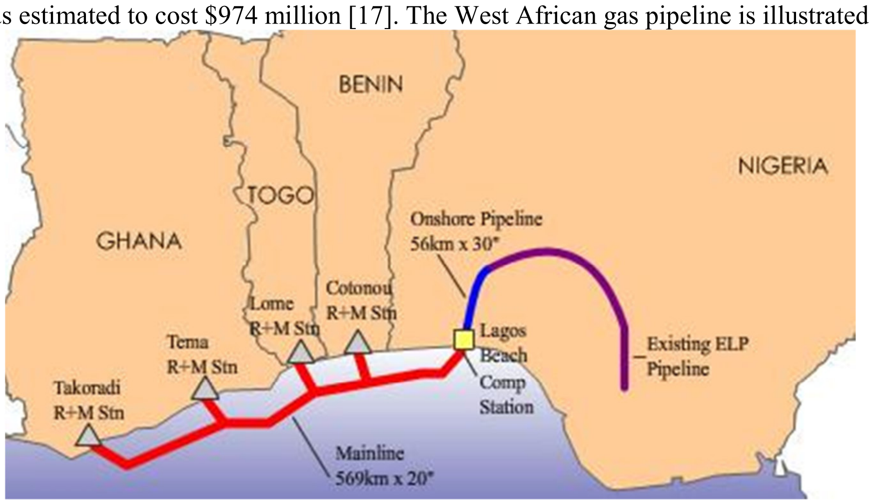

Figure 3: West African Gas Pipeline. Sourced: West African Gas Pipeline Company [21]

As at May 2008, there are more than 1000 kilometres connected gas pipelines within the Nigerian territory, which are concentrated in the Niger Delta region. Other pipelines beyond the gas-producing region are the Ajaokuta gas pipeline and the main Nigerian Escravos-Lagos Pipeline system that links the pipelines to the Lagos beach, which links to the West African gas pipeline and for further transportation via LNG or extended pipeline. The following table represents a summary of the existing major gas pipeline networks in the country. The map of the major gas networks is presented in figure 4 [22].

Table 1: Major Gas Pipeline Networks within Nigerian Border

Project Name	Start Point	End Point	Diameter (inches)	Length (Kilometres)
Transmitting System	Banga Field	Bonny Terminal	32	268
Escarvos-Lagos Pipeline System (ELPS)	Escravos	Lagos	36	340
Aladja System Pipeline	Oben	Ajaokuta	24	294
Greater Ughelli System	Ughelli	Warri	-	90.3

Figure 4: Map of major gas pipelines in Nigeria: gas pipelines indicated by the bold red lines. [23]

The four major gas transmitting pipelines in Nigeria covering slightly more than 1000 kilometres of land, supply gas to few power, cements and fertilizer plants. Nigerian Gas Company further expanded the chart of the Nigerian gas pipeline systems by considering other small distant pipelines and by looking at their destinations to various industrial companies and power stations as follows [24]:

1. The Aladja Gas Pipeline System which supplies the Delta Steel Company, Aladja.
2. The Oben-Ajaokuta-Geregu Gas Pipeline System, supplies Gas to Ajaokuta Steel Company, Dangote's Obajana Cement Company and PHCN Geregu Power Plant.
3. The Sapele Gas Supply Systems which supplies gas to PHCN Power Station at Ogorode, Sapele.
4. The Imo-River-Aba System for gas supply to the International Glass Industry Limited PZ, Aba Textile Mills and Aba Equitable Industry.
5. The Obigbo North -Afam system caters for PHCN Power Station at Afam,
6. The Alakiri to Onne Gas pipeline system supplies gas to the National Fertiliser Company (NAFCON) now Notore Chemicals for fertilizer production;
7. The Alakiri -Obigbo North -lkot Abasi system for gas supply to the former Aluminum Smelting Company of Nigeria (ALSCON) Plant now Rusal Industries in Ikot Abasi.

8. The Escravos-Lagos Pipeline (ELP), which supplies gas to NEPA's Egbin Power Plant near Lagos. Subsequent spur lines from the ELP supply the West African Portland Cement (WAPCO) Plants at Shagamu and Ewekoro, PZ Industries at Ikorodu, City Gate in lkeja Lagos, PHCN Delta IV at Ughelli, and Warri Refining and Petrochemical Company at Warri.
9. Ibafo – Ikeja Gas Supply Pipeline System supplies gas to Ikeja City Gate from where Gaslink distributes to the Lagos Industrial Area (LIA).
10. Ikeja – Ilupeju – Apapa Gas Pipeline System currently operated by Gaslink for Gas Supplies to Greater Lagos Industrial Area.
11. Ajaokuta – Geregu Gas Pipeline System, which supplies gas to the Geregu PHCN Power Plant.
12. Ajaokuta – Obajana Gas Pipeline System, which supplies gas to Dangote's Obajana Cement Plant (OCP).

"All these facilities comprise of over 1,250 kilometres of pipelines ranging from 4" to 36" in diameters with an overall design capacity of more than 2.5 billion standard cubic feet of gas per day (bscf/d), 16 compressor stations and 18 metering stations. The facilities represent a current asset base of more than N21 Billion business contact" Nigerian Gas Company Limited (2012) [24]. There are other pipeline projects going on, and some are being proposed. The on-going projects include the expansion of the existing pipelines and extension of pipelines to new areas, especially the Northern part of the country, where there is no single pipeline network despite the largeness of the region and huge human population, which comprises almost 56% of the nation total population of more than 160million people [25].

3. Analysis of New Gas Pipelines in Nigeria

3.1. Possible routes options for gas transportation in Nigeria

This research considers the proposed Nigerian gas pipeline route options as contained in the gas master plan, which will be used to transport gas from the Niger Delta area (the Nigerian oil and gas rich region) to major expected gas demand areas within Nigeria. The Nigerian gas master plan proposed gas pipeline systems which will be constructed in a near future, and some possible future extensions. There is a trunk line proposed from South to North, which is an integral part of the near future plans as well as possible future extension plans. The trunk line is the system that will be supplying gas to the future gas pipeline extensions. Similarly, irrespective of the decision among these extensions, the trunk line is integral and is designed to provide a connecting system to the proposed trans-Sahara gas pipeline. Therefore, this trunk line will be considered as the Base Route Option (BRO), and will be assessed independently at first instance. The South-western extensions, which is part of the near future plan will be assessed separately and will be termed South-western Route Option (SRO), and then the future potential extensions will also be assessed separately and will be termed Northern Route Option (NRO). In addition, the BRO will be assessed in combination with SRO, which means all the near future gas pipeline plans together, which are termed BSRO, and then the BRO with NRO separately, which are termed BNRO. Finally, all the three possible options will be assessed together.

The aim is to use economic models to estimate the investment costs of these six options, and then assess their costs and benefits using the indicators specified above. This will help in recommending the most viable route option or combination economically, so as to inform government and other prospective investors when investing in gas pipelines project in the country on the optimal route combination so as to optimise their investments. This will also justify which of the possible combination is optimal to build. In other word, to justify whether the combination of the near future pipeline networks are more optimal and cost effective than the other possible combinations.

The research does not consider costs associated with production, processing and/or purification of the gas. All models are built on the assumption that any volume of gas to be transported via any of the optional pipelines will be composed of the required gas specification suitable for the pipeline. Further geographical illustration of these options are presented in Appendices: Their starting pressure is estimated at 60 bar as specified in the plan.

3.2. Methodology

This research reports on the economic methodology in assessing the economics of the gas pipelines in Nigeria. To assess the costs and benefits of the six different gas pipeline routes combinations, first, the investment cost comprising of gas pipeline material cost, pipe coating and wrapping cost, cost of constructing the compressor stations, and labour cost will be estimated using the models below. The gas delivery and cost of capital of each of the pipelines will be estimated as well as the annual costs and benefits for running the gas pipeline routes using the NPV, IRR and payback period methods. The initial investment cost of these pipelines are estimated using equation 1 [12].

$$Initial\ Investment\ costs(IIC) = E(CCP) + E(CCMS) \quad (1)$$

Where E (CCP) stands for the expected cost of constructing/laying down the gas pipelines and E (CCMS) is the expected cost of installing compressor stations. Cost of constructing the pipeline consists of the fixed cost of the system including the cost of material and right of way (ROW) if applicable. It consists of the costs of process equipment, supporting facilities, direct/indirect labour etc. The formula for pipeline construction cost is given as follows [12]:

$$E(CCP) = PMC + PCW + LC \quad (2)$$

Where PMC is the pipe material cost and PCW is the cost of pipe coating and wrapping and LC stands for the labour cost of installing the pipeline.

To estimate the cost of laying down a pipeline, i.e. E(CCP), we will adopt the model established by Shahi Menon (2005) [12], which suggested that the costs of constructing a pipeline include the costs of pipe materials, pipe coating and fittings, and the cost of labour for installation. These parameters were incorporated in equation 2, and are defined as follows:

$$PCW = PMC \times 5\% \quad (3)$$

Therefore, the PCW is 5% of the pipe material cost, which is defined in equation 4

$$PMC = 0.0246(D - T)TLC \quad (4)$$

Where:

D is the diameter (outside) of the pipe in millimetres (mm), L stands for the length of the pipe in km, T stands for the pipe wall thickness in mm and C is the pipe material cost in $/metric ton [14]. Estimating the labour cost during the installation can be difficult depending on the area where the pipe will be laid down and the contractor. It also depends on the length of the pipe and from where the pipes are brought. According to Mohitpour, et al (2003), the labour cost for laying the gas pipeline was estimated to be $316,800 per mile, which is $196,850.39 per kilometre. However, this may vary depending on the location and nature of the environment; the contractors normally study the nature of the work and fix cost for labour. From historical data and some gas construction figures, a fixed amount is slated for every diameter and distance of the pipeline, which is normally $15, 000 as average labour cost during pipe installation [26]. This is based on the external labour cost of gas pipeline installations as the pipe installation company is expected to be a foreign company (likely from America), and the engineers will be paid based on the international labour cost. For the purpose of this estimation we adopt the following model [12].

$$LC = \$15,000 \times diameter\ (in) \times length\ (miles) \quad (5)$$

For the cost of constructing and installing the compressor stations, we still adopt the model established by Shahi Menon (2005) which estimates the compressor cost as $2000 per Horsepower capacity of the compressor. This is corroborated in the work of Yipeng Z. and Zhenhua R. (2014) [27]. Intervals between compressor stations are between 40 and 60 miles (64 and 161km) [28], and the minimal intervals is adopted in order to maintain high pressure in the gas. Therefore, the cost of compressors of a pipeline will be $2000 multiply by number of compressors and then multiply by the Horsepower capacity of the compressors.

$$E(CCMS) = \$2000 * Horsepower * number\ of\ compressors \quad (6)$$

The pipeline thickness (t) is derived through the following equation adopted from Shahi Menon (2005).

$$t = \frac{D_O - D_I}{2} \quad (7)$$

Where D_O is the diameter outside, and D_I is the diameter inside.

Depreciation and taxation are also accounted. Straight-line depreciation method is used, which is an accounting way of calculating the devaluation of an item at a fixed rate over a long period of time [29]. It is the opposite of declining balance method, where the asset depreciates more in the first year and then depreciates less every other year of its lifetime. Straight Line depreciation divides the total value of the asset by its operational period to derive the annual depreciation amount, which means at the end of the business period (40 years), the book value of the asset will be zero. However, because we will have a salvage value (SV) of the gas pipelines in our analysis, a salvage value will be considered, which is deducted from the value of the pipelines before applying the straight-line depreciation, and is given as follows [30] [31]:

$$SV = IIC * (1 - dr)^{lifetime} \quad (8)$$

Where

$$dr = \left(\frac{IIC}{life\ time}/IIC\right) \times 100 \quad (9)$$

Where dr is the depreciation rate.

Depreciation relates to taxation, because corporate tax rate is charged against the depreciation value of the asset to arrive at the tax benefit. Usually companies deliberately over depreciate their assets in order to pay less of their taxes [32]. Depreciation is deducted in the cost, thereby reducing the taxable income. Therefore, depreciation tax benefit is the relief or discount of a tax the gas pipeline operator receives for the depreciation of the pipeline, which will be considered as a benefit not a cost [33]. The tax benefit is derived by multiplying the tax rate by the annual depreciation value, which will then be deducted from the total tax payment to arrive at total tax payable [34]. Since the proposed gas pipelines are within Nigerian territory, the complexity of using different corporate tax rates will not arise.

Annual operating and maintenance costs (O and M) have to be considered even though the pipelines are not in operation, but an assumption can be made based on the existing literature, and adopt a fixed percentage of the investment cost (equation 1) to be the annual O and M costs. However, since the Nigerian pipeline will connect through the onshore land of the Nigerian territory, 2% of the costs of constructing the pipeline will be assumed to be the O and M costs annually [35] [36] [37]. O and M costs consist of costs of labour, supervision, energy, telecommunication, miscellaneous etc. The 2% was considered as a result of including the operation costs, otherwise the cost of maintaining the pipeline would have been below the 2% of the initial investment cost [12].

The capital structure of the gas pipelines investment will be 60% debt and 40% equity, and this is in line with the capital structure of the proposed domestic gas pipelines [16], and it is the capital structure of an average oil and gas listed companies in the country, with particular reference to Nigerian Oando plc [38]. However, the Nigerian government is recommended to own substantive part of the business [16].

Therefore, the cost of capital will be accounted through the cost of equity and cost of debt for all the investments appraisal. The cost of equity will be accounted using the Capital Asset Pricing Model (CAPM), and the after tax cost of debt will be used. To account for both cost of debt and cost of equity, the Weighted Average Cost of Capital (WACC) will be applied, and from which all the cash flows will be discounted [39] [40]. The WACC is used because it accounts for both costs of the two sources of capital, which are debt and equity [39] [40].

$$WACC = \frac{E}{C} * k_e + \frac{D}{C} * k_d \, (1 - TR) \tag{10}$$

Where E is the total value of the equity, C is the total value of the capital, D is the total value of the debt, k_e is the cost of equity, k_d is the cost of debt and TR is the tax rate, which is 30 percent in Nigeria [41]. Starting with the cost of debt, we will use the after tax cost of debt going by [40], which is:

$$k_d = r * (1 - TR) \tag{11}$$

Where, r is the prime lending rate of the Nigerian commercial bank, which is 16.90% as at March 2015 [42], and which has been the average prime lending rate for a decade [43]. This rate is used based on the assumption that the debt to fund these projects will be provided by a bank within Nigeria. The formula for cost of equity using CAPM model is stated in equation 12 [31].

$$k_e = r_f + \beta(r_m - r_f) \tag{12}$$

Where, k_e is the cost of equity, r_f is the risk free interest rate, r_m is the expected market portfolio return, and the difference between r_m and r_f is the equity risk premium (ERP), which measures the additional compensation to the investor for taking the risk of investing in a riskier business, and β accounts for responsiveness of the business to the average stock market change, hence how risky is the business. r_f is usually the interest rate of a relatively risk free investment, which the investor may wish to invest in, it is usually a government bond, which have higher level of security, and hence low risk. The higher the risk, the higher the expected interest rate [44]. The yield on the Nigerian government bond is used as the risk free interest rate. According to the trending economics, the yield on the Nigerian government bonds has averaged around 13.04 percent from 2007 to 2015. The return on the bonds changes frequently, and as at July 2015, the rate was 14.81 percent. The highest it has ever being was 17.30 percent in February 2015, and lowest it has been was 6.04 percent in March 2010. Due to these erratic fluctuation of the return on the bonds, the average return on the bonds from 2007 to 2015 will be used, which is 13.04 percent [45] [46].

The ERP as mentioned is the difference between the rate of return on a risk free investment and the expected market rate of return of the investment [44].The Nigerian estimated average ERP as contained in Moody's report and the Stalwart report as at January 2015 was 11.15 percent, so we will use the latest ERP for this analysis, which is 11.15 percent [47] [48]. Therefore, the expected market portfolio return can be assumed to be 11.15 percent plus 13.04 percent risk free rate, and this gives 24.19 percent as the expected market portfolio return. This will be the maximum return the investor will expect for investing in the riskier investment, and it will be the r_m in equation 12. The Risk Premium is higher compare to some other countries, and this may suit this kind of business due to some country risk factors associated with it, which includes the potentials of gas pipeline vandalism, which have been frequent recently causing loss of gas and extra cost of repair. There is also security risks associated with kidnapping and killings of oil and gas personnel by the militants. There are political and economic risks in the country, associated with changes of government and economic policies.

Now the next variable to identify is the β (Beta). Beta measures the reaction of a price of a share in a company to the change in the overall stock market. A Beta lower than 1 shows that the stock value is less volatile than the stock market, and if it is higher than 1, it shows that it is more volatile than the market. The formula for the Beta is given as the covariance between the unlevered return on the business (R_j) and that of the market (R_m), divided by the variance of the latter, which is presented as follows [44].

$$\beta_j = \frac{Cov(R_j, R_m)}{Var(R_m)} \tag{13}$$

Because there is no available data for Nigerian stock market for domestic gas pipeline investment, as there are no listed gas pipeline companies in the country, the average $Beta$ of seven listed oil and gas companies (BOC Gases Nigeria PLC, Conoil PLC, Eterna Plc, Forte Oil Plc, Mobil Oil Nigeria Plc, MRS Oil Nigeria Plc, Oando Plc) in the country is used as the proxy Beta for the investments, which was 0.86 as at July 2015 [49] [38] [50, 51].

Since debt is included in the capital structure, the amortization cost will be accounted using the following formula [50]

$$Annual\ amortization\ cost = \frac{Debt \times interst\ rate}{1-\left(\frac{1}{(1+interest\ rate)}\right)^{N}} \quad (14)$$

Where, N is the total number of period. To calculate the certified volume of gas/capacity of a pipeline (where applicable), the Weymouth formula is used as provided in pipeline rules of thumb [52], which assumed that the optimum number of compressors are in place to achieve the desired pressure level of the gas at the destination using the lowest compressor station intervals as stated earlier, and is presented in equation 15:

$$Q = \frac{(871)(d^{\frac{8}{3}})\sqrt{P_1^2 - P_2^2}}{\sqrt{L}} \quad (15)$$

Where:
Q= Cubic feet of gas per 24 hours
d= pipeline inside diameter in inches
P_1= Psi (abs) at starting point
P_2=Psi (abs) at ending point
L = Length of the pipeline in miles

For the annual gas delivery of the gas pipeline, equation 16 applied the availability rate and the annual gas delivery capacity to arrive at the actual gas delivery of the pipeline. [33] [52].

$$\sum_{n=1}^{N} Availability\ factor \times annual\ pipeline\ capacity\ (Mcf) \quad (16)$$

The Nigerian regulated gas transportation cost of \$0.80/Mcf is used [53] [54] [55]. This is almost similar to the estimated average cost of gas transportation for the five segments of the Nord stream (Gryazovets-Vyborg, Nord-Stream offshore, Opal, and Nel), which was estimated to have an average levelised cost of gas transportation of \$0.81/Mcf (\$28.7/thousand cubic metres) [33]. The regulated tariff in the country did not account for distance, and as such it is highly recommended to review this tariff and account for distance. For the availability/utilization rate, 80% is applied based on the existing pipelines average availability rate in the country, and this accounts for the number of days that the pipeline will be operational[24] [20] [21] [56]. Other non-operational period could be due to fall or stop in supply/patronage, or for holidays, or for maintenance purposes or as a result of vandalism etc

The Net Present Value (NPV) accounts for the difference between the initial investment cost and the present values of all the future cash inflows and cash outflows. Therefore, NPV is the difference between the present value of the future net cash flows and the initial investment cost. For the Internal Rate of Return (IRR), it is the maximum allowable rate of return on the investment, it is the discount rate that brings the business to breakeven, where NPV equals to zero. It is derived by trying so many discount rates, and the discount rate that makes the NPV zero is the IRR. Payback period is the number of years that the investor will have to wait to get back his/her initial investment [44].

The net present value and the IRR will be derived from these cash flows. The Net Present Value formula is presented as follows:

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} \dots\dots\dots\dots \frac{C_T}{(1+r)^T} \quad (17)$$

Where, C_0 is the initial investment cost, Cs are the net cash flows of respective periods, r is the discount rate, and T is the end period. IRR is the discount rate at which the NPV equals to zero. The discounted payback period is derived by dividing the absolute value of the last negative cumulative discounted cash flow by the discounted cash flow value in the following year and then adding the period of the last negative cumulative discounted cash flow, this is presented in equation 18 below [34].

$$Discounted\ payback\ Period = A + \frac{B}{C} \quad (18)$$

Where A is the period where last negative cumulative discounted cash flow was recorded, B is the absolute value of the last negative cumulative discounted cash flow at period A, and C is the discounted cash flow value after the period A.

Using all the above costs and benefits inputs, an annual cash flow of these investments will be derived and discounted to arrive at the net present value, IRR and Payback period, which will be used for comparison.

3.3. Costs and Benefits of the Combination of BSRO Pipelines (Near Future Plans)

The step by step analysis of the business option that combines the BRO and SRO will be presented. This combination is what represents the intended near future gas pipeline plan. Other options will follow similar step by step analysis, and their IIC compositions as well as their accounting estimation results will be presented.

Now, we will present step by step analysis of the combination of the BRO and SRO, which is abbreviated as BSRO. The equation for estimating initial investment costs (IIC) is already presented in equation 1:

First, we need to find the pipeline thickness (t), which is derived as follows following equation 7. For the BSRO's 3a segment, which has 42 inch diameter, the following wall thickness is calculated, which will be used for the entire analysis, as thickness for other pipelines will be the same.

$$t_{BSRO_{1a}} \frac{42in - 41in}{2} = 0.5in\ (12.7mm) \quad (19)$$

Equation 19 calculated the wall thickness of the 3a sub-segment of the BSRO pipelines network (Warri-Shagamu). We will adopt 0.5 inches as wall thickness on all other pipelines. We will also use the pipe material cost of $800 per tonne as sourced from Shahi Menon (2005), Mohitpour et al (2003) and Tianjin Yuheng Steel Co., Ltd. [26] [57] [12]. The PMC of the three segments and sub-segments of the BSRO are presented in table 2.

Table 2: Pipeline Material Cost of BSRO pipelines

Pipeline	Diameter	Length (km)	Pipeline Thickness (mm)	Pipe material cost ($/metric ton)	PMC ($)
1. South-North:					
1a. Calabar to Ajaokuta	56	490	12.7	800	5,302,892.11
1b Ajaokuta to Kaduna	48	495	12.7	800	4,367,256.70
2. Interconnector: Obiafu-Oben Node	42	100	12.7	800	732,312.48
3. Four segments of West-Escravos ext.					
3a: Warri-Shagamu (offshore)	42	200	12.7	800	1,464,624.96
3b: Ore-Ondo-Ekiti	24	125	12.7	800	353,034.6
3c:Shagamu-Ibadan-Osun-Jebba	24	321	12.7	800	906,592.85
3d: Shagamu -Papalantro	16	40	12.7	800	32,991.552
Total					**13,159,705.25**

Table 2 shows that the estimated material cost for the BSRO pipelines are approximately $13 million. Going by equation 5, the labour cost of installing the BSRO pipelines are estimated in table 10 below.

Table 3: Cost of labour for constructing BSRO pipelines

Pipeline	Diameter	Length (MILES)	Labour cost ($15,000)	Labour cost (subtotal $)
1. South-North:				
1a Calabar to Ajaokuta	56	304.486	15000	255,768,240
1b Ajaokuta to Kaduna	48	307.593	15000	221,466,960
2. Interconnector: Obiafu-Oben Node	42	62.14	15000	39,148,200
3a: Warri-Shagamu (offshore)*	42	124.28	15000	228,625,488
3b: Ore-Ondo-Ekiti	24	77.675	15000	27,963,000
3c:Shagamu-Ibadan-Osun-Jebba	24	199.4694	15000	71,808,984
3d: Shagamu -Papalantro	16	24.856	15000	5,965,440
Total				**850,746,312.00**

*The offshore gas pipeline labour cost is assumed to be 192% higher than the onshore gas pipelines [58]

PCW of the BSRO pipelines will then be 5% of the total in table 2, which will be $657,985.30. Therefore, $E(CCP)_{BSRO}$ will then be the summation of PMC, PCW and LC, as presented as follows:

$$E(CCP)_{BSRO} = \$13{,}159{,}705.25 + \$657{,}985.30 + \$850{,}746{,}312.00 = \$864{,}564{,}002.52 \quad (20)$$

Reference to equation 6, the cost of compressor stations of the BSRO pipelines are estimated in table 4. Due to very low distance of the fourth segment of the West-Escravos extension (3d segment), a compressor capacity of 2000 Horsepower (HP) is used, while 5000HP capacity is used for other segments. The costs of compressor capacity is used as $2000 per HP, which is all-inclusive costs, and include "material and equipment cost and the labour cost for installing the compressor equipment, piping, valves, instrumentation, and controls within the compressor stations" [59] [12]. The calculation is shown in table 4 below:

Table 4: Cost of Constructing Compressor Stations E(CCMS) for BSRO pipelines

Pipeline	Diameter	Length (km)	Compressors (At each 64 km) Compressors (At each 64 km)	Horsepower	Cost of compressor ($2000*HP*num-ber of compressors) ($)
1. South-North:					
1a Calabar to Ajaokuta	56"	490	8	5000	80,000,000.00
1b Ajaokuta to Kaduna	48"	495	8	5000	80,000,000.00
2. Interconnector: Obiafu-Oben Node	42"	100	2	5000	20,000,000.00
3. Four segments of West-Escravos extensions					
3a: Warri-Shagamu (offshore)	42"	200	3	5000	30,000,000.00
3b: Ore-Ondo-Ekiti	24"	125	2	5000	20,000,000.00
3c:Shagamu-Ibadan-Osun-Jebba	24"	321	5	5000	50,000,000.00
3d: Shagamu -Papalantro	16"	40	1	2000	4,000,000.00
Total Compressor investment cost					**284,000,000.00**

The total cost of compressor stations for the BSRO pipelines is $284 million. Reference to equation 1, the initial investment cost for the BSRO pipelines can be derived as follows:

$$IIC_{BSRO} = \$864{,}564{,}002.52 + \$284{,}000{,}000 = \$1{,}148{,}564{,}002.52 \quad (21)$$

Where, IIC is the estimated initial investment cost. Now to calculate the annual depreciation of the pipelines, a **straight**-line **depreciation method** is applied. The depreciation rate equation is given in equation 9 [60]:

$$dr_{BSRO} = \frac{\$1{,}148{,}564{,}002.52}{40} / \$1{,}148{,}564{,}002.52 = 2.5\%\ annually \quad (22)$$

Where, dr_{BSRO} is the depreciation rate for the BSRO pipelines. The result (2.5%) is the rate at which the value of the BSRO pipelines will depreciate annually. However, the pipelines are expected to have a salvage value (SV) at the end of its operation period. Salvage value is the residual value of the pipeline after depreciations, and it is calculated going by equation 8. The SV of the BSRO pipelines are given in equation 23.

$$SV_{BSRO} = \$1{,}148{,}564{,}002.52 * (1 - 0.025)^{40} = \$\ 417{,}195{,}705.00 \quad (23)$$

That means the residual value of the BSRO pipelines will be $417 million after forty years of operation. Therefore, the total of $731,368,297.52 (the net value of the pipeline after salvage value is deducted) is going to be depreciated over the period of forty years using the SLD method, which gives $18,284,207.44 as the annual depreciation figure for the BSRO pipelines.

The annual tax benefit of BSRO pipelines is derived by multiplying the value of the annual depreciation by the tax rate. Adopting the corporation tax rate in Nigeria of 30% [61], the annual tax benefit will be $5,485,262.23.

For the annual operation and maintenance costs of the BSRO pipelines, which includes the maintenance of the compressor stations, we adopt 2% of the IIC value [35] [36] [37], which is $ 22,971,280.05 per annum. This figure is close to what Shahi (2005) and Francesco 2011 estimated to be the O and M cost of a pipeline [62] [63].

The O and M cost of a pipeline includes also the fuel costs for compressor stations, electric power, costs of equipment services and repair, pipe maintenance, pipe patrol, communication costs, meter stations maintenance, administrative and payroll. This is also expected to be low due to the low labour cost in Nigeria. There is no formal labour cost index in Nigeria. However, there is a minimum wage of $120 per month in the public sector. This is less than US dollar per hour. When compare with the USA's and UK's average minimum wages of $7.70 and £6.19 per hour respectively, we can expect lower labour cost in Nigeria than in USA and UK [64] [65].

The next figure is for the volume of gas to be transported through the BSRO pipelines. For the flow of gas in the pipelines, we will use an average ^{0}F 86 (30^{0}C) average annual temperature in Nigeria [66], and pressure of 60 bar at the starting point [1], with expected drop of pressure of 3.245 bar/100km (0.03245bar/km) provided the adequate number of compressors are provided based on our estimate of compressor intervals going by [67], [52] and [67].

Reference to equation 14, table 5 reports on the estimated gas capacity/volume of the segments of BSRO pipelines:

Table 5: Gas Capacity for BSRO pipelines

Pipeline	Diameter	Length (km)	Capacity mcm/yr
1. South-North:			
1a Calabar to Ajaokuta	56	490	22110.54
1b Ajaokuta to Kaduna	48	495	(14721.33)*
2. Interconnector: Obiafu-Oben Node	42	100	4906.73
3. Four segments of West-Escravos extensions			
3a: Warri-Shagamu (offshore)	42	200	6844.68
3b: Ore-Ondo-Ekiti	24	125	1229.30
3c:Shagamu-Ibadan-Osun-Jebba	24	321	1916.12
3d: Shagamu -Papalantro	16	40	238.60
*This figure is not added as it was already counted in 1a figure.			**37245.97**

The BSRO pipelines have a certified operating capacity of 37.24 bcm per year. "Certificated capacity represents an average level of service that can be maintained over an extended period of time, and not the maximum throughput capability of a system or segment on any given day" [56].

$$Cummulative\ gas\ volume\ in\ Mcf = \sum_{n=1}^{N}((37.24597\ \ 10^9\ \text{m}^3\ \times 35.3146667) \times 0.80/1000) = 1{,}052{,}263{,}213.17\ \text{Mcf} \quad (24)$$

Where, 35.3146667 is the conversion factor from cubic metres to cubic feet. Therefore, around 1.1 billion Mcf of gas will be transported along the gas pipelines annually.

The cost of capital will be accounted using the WACC, and from which the net cash flows will be discounted. We will first use CAPM as described in equation 12 to calculate the cost of equity of these gas pipelines [39] [40].

As earlier established, a Beta of 0.86 will be used for the gas pipelines, a risk free rate of 13.04%, and expected market portfolio return of 24.19% will be applied. For this project, and with reference to equation 12, the cost of equity (k_e) will be as follows:

$$k_e = 0.1304 + \ 0.86(0.2419 - 0.1304) = 0.2263(\ 22.63\%) \quad (25)$$

The unweighted cost of equity is 22.63% for this project, this tells potential investors of the opportunity cost of capital of their current or intended investment elsewhere. The cost of debt for the gas pipelines is presented in equation 26 with reference to equation 11.

$$k_d = 0.169 * (1 - 0.30) = 11.83\% \quad (26)$$

Therefore, with reference to equation 10, the weighted average cost of debt and equity for the gas pipeline investments will be:

$$WACC = (0.40 * 0.2263) + (0.60 * 0.1183) = \ 0.1615(\ 16.15\%) \quad (27)$$

The WACC of the gas pipeline investments is 16.15% and will be used as the discount rate to account for the cost of capital and time value of money [44]. The amortization cost will then be, with reference to equation 14:

$$Annual\ amortization\ cost = \frac{\$689{,}138{,}401.51 \times 0.169}{1-\left(\frac{1}{(1+0.169)}\right)^{40}} = \$116{,}690{,}570.44 \quad (28)$$

Approximately $117 million is the annual amortization cost for the BSRO pipelines. Table 6 below reports about the specific costs and benefits elements of the BSRO pipelines:

Table 6: Cost and Benefits of the BSRO pipelines

BSRO Pipeline system	Item
Capital cost ($)	1,148,564,002.52
Equity ($)	459,425,601.01
Debt ($)	689,138,401.51
Interest rate (prime lending rate)	16.90%
Cost of debt (after tax)	11.83%
Beta	0.86
Free risk rate	13.04%
Equity risk premium	11.15%
Market Portfolio Return	24.19%
Cost of equity (CAPM)	22.63%
WACC	16.15%
Amortization cost ($)	116,690,570.44
Depreciation rate	2.5%
Salvage Value ($)	417,195,705.00
Depreciating Value ($)	731,368,297.51
Annual Depreciation	18,284,207.44
Tax Rate	30%
Annual O and M cost	22,971,280.05
Annual Gas delivery (bcm)	37.25
Annual Gas delivery in Mcf	1,315,329,027.25
Availability factor (days of operation/yr)	80%
Actual Gas delivery (Mcf)	1,052,263,221.80
Transportation cost of Natural Gas $/Mcf	0.80
Annual Revenue ($)	841,810,577.44
Net Annual Revenue ($)	818,839,297.39
Gross tax payments ($)	245,651,789.22
Tax benefit from depreciation ($)	5,485,262.23
Tax Payable ($)	240,166,526.99
Annual Cash Flow ($)	578,672,770.40
Additional cash flow in final year	
Salvage value ($)	417,195,705.00
Tax on selling at salvage value ($)	125,158,711.50
Net Gain ($)	292,036,993.50

Table 6 represents summary of all the costs and benefits elements mentioned earlier. The table shows that $0.80 is charged for transporting each thousand cubic feet of natural gas along the pipelines as earlier established. It also showed that at the end year of the business, there will be additional cash flow as a result of the SV of the pipelines. The table shows that the BSRO pipelines have certified gas delivery capacity of 1.5 billion Mcf per year with availability factor of 80%. The annual O and M was estimated at $23 million, and after tax net cash flow of around $812 million was derived, which is used as the fixed annual cash flow for the duration of the business span, and then discounted in the NPV calculations as shown in table 7 below.

Table 7: Discounted Cash flow of the BSRO pipelines

Year	Cash flow	Discount Factor	Discounted Cash Flow	Cumulative DCF
0	$ -1,148,564,002.52	1	$ -1,148,564,002.52	$ -1,148,564,002.52
1	$ 578,672,770.40	0.860958626	$ 498,213,313.18	$ -650,350,689.34
2	$ 578,672,770.40	0.741249755	$ 428,941,049.46	$ -221,409,639.88
3	$ 578,672,770.40	0.638185371	$ 369,300,496.48	$ 147,890,856.60
4	$ 578,672,770.40	0.5494512	$ 317,952,447.94	$ 465,843,304.54
5	$ 578,672,770.40	0.47305475	$ 273,743,902.64	$ 739,587,207.18
6	$ 578,672,770.40	0.407280567	$ 235,682,174.23	$ 975,269,381.42
7	$ 578,672,770.40	0.350651718	$ 202,912,600.85	$ 1,178,181,982.26
8	$ 578,672,770.40	0.301896621	$ 174,699,353.98	$ 1,352,881,336.24
9	$ 578,672,770.40	0.2599205	$ 150,408,915.72	$ 1,503,290,251.96
10	$ 578,672,770.40	0.223780796	$ 129,495,853.38	$ 1,632,786,105.35
11	$ 578,672,770.40	0.192666007	$ 111,490,571.97	$ 1,744,276,677.32
12	$ 578,672,770.40	0.165877461	$ 95,988,769.63	$ 1,840,265,446.95
13	$ 578,672,770.40	0.14281363	$ 82,642,359.19	$ 1,922,907,806.15
14	$ 578,672,770.40	0.122956627	$ 71,151,652.00	$ 1,994,059,458.15
15	$ 578,672,770.40	0.105860569	$ 61,258,628.53	$ 2,055,318,086.67
16	$ 578,672,770.40	0.09114157	$ 52,741,144.63	$ 2,108,059,231.31
17	$ 578,672,770.40	0.078469121	$ 45,407,943.41	$ 2,153,467,174.71
18	$ 578,672,770.40	0.067558666	$ 39,094,360.55	$ 2,192,561,535.27
19	$ 578,672,770.40	0.058165216	$ 33,658,626.94	$ 2,226,220,162.21
20	$ 578,672,770.40	0.050077845	$ 28,978,685.19	$ 2,255,198,847.40
21	$ 578,672,770.40	0.043114952	$ 24,949,448.98	$ 2,280,148,296.38
22	$ 578,672,770.40	0.03712019	$ 21,480,443.31	$ 2,301,628,739.69
23	$ 578,672,770.40	0.031958948	$ 18,493,772.95	$ 2,320,122,512.64
24	$ 578,672,770.40	0.027515332	$ 15,922,373.35	$ 2,336,044,885.99
25	$ 578,672,770.40	0.023689562	$ 13,708,504.68	$ 2,349,753,390.66
26	$ 578,672,770.40	0.020395733	$ 11,802,455.35	$ 2,361,555,846.01
27	$ 578,672,770.40	0.017559882	$ 10,161,425.74	$ 2,371,717,271.75
28	$ 578,672,770.40	0.015118332	$ 8,748,567.14	$ 2,380,465,838.88
29	$ 578,672,770.40	0.013016258	$ 7,532,154.34	$ 2,387,997,993.22
30	$ 578,672,770.40	0.01120646	$ 6,484,873.25	$ 2,394,482,866.47
31	$ 578,672,770.40	0.009648298	$ 5,583,207.56	$ 2,400,066,074.04
32	$ 578,672,770.40	0.008306786	$ 4,806,910.71	$ 2,404,872,984.74
33	$ 578,672,770.40	0.007151799	$ 4,138,551.24	$ 2,409,011,535.98
34	$ 578,672,770.40	0.006157403	$ 3,563,121.39	$ 2,412,574,657.37
35	$ 578,672,770.40	0.005301269	$ 3,067,700.09	$ 2,415,642,357.46
36	$ 578,672,770.40	0.004564173	$ 2,641,162.86	$ 2,418,283,520.32
37	$ 578,672,770.40	0.003929564	$ 2,273,931.94	$ 2,420,557,452.26
38	$ 578,672,770.40	0.003383192	$ 1,957,761.32	$ 2,422,515,213.58
39	$ 578,672,770.40	0.002912789	$ 1,685,551.50	$ 2,424,200,765.08
40	$ 870,709,763.90	0.002507791	$ 2,183,557.71	$ 2,426,384,322.79
		NPV	$ 2,426,384,322.79	

The BSRO pipelines have a positive NPV of approximately $2.4 billion for the period of forty years of operation. This averaged around $61 million present value of operating net cash flows per annum. This means that the business cash flow can meet up with all the operating costs and still return a positive profit. This also means that the present value of the future cash inflows are higher than the present value of the current and future cash outflows by $2.4 billion. Its internal rate of return was estimated to be 50.38%, which is higher than the discount rate for the period of forty years. This means investment return of this business can return up to 50.38%. The investors can aim higher investment return up to 50.38% as the business only become at breakeven when the investment return is at 50.38%. This means that the business can be well preferred compare to other potential investments, which could offer lower IRR than 50.38%. The IRR is much higher than the discount rate, which means, the business will not be tight by allowing investment return at the calculated discount rate, and can even give higher investment return than the discount rate. The BSRO pipelines investment also has a discounted payback period of 2.60 years. These indicate that the BSRO pipelines are highly viable.

The major costs and benefits inputs and indicators of the remaining five options are presented in the following tables. The summary of capital cost elements of other gas pipeline options will be presented accordingly. Analytical comparison of the costs and benefits of these gas pipelines options will be presented.

3.4. Costs and Benefits of other gas pipeline route options

Having looked at the costs and benefits of the near future planned route option (BSRO), other possible gas pipeline routes options will be assessed in the same manner. The capital cost components of the remaining five options are presented in table 8 below:

Table 8: Initial Investment Cost elements of the Gas pipelines route options

Pipelines	All possible Pipeline routes option	BRO	SRO	NRO	BNRO
PMC ($)	20,891,445.42	9,670,148.81	3,489,556.44	7,731,740.17	17,401,888.98
PCW ($)	1,044,572.27	483,507.44	174,477.82	386,587.01	870,094.45
Labour cost ($)	1,836,282,312.00	477,235,200.00	373,511,112.00	985,536,000.00	1,462,771,200.00
Cost of Compressor stations($)	714,000,000.00	590,000,000.00	124,000,000.00	430,000,000.00	590,000,000.00
Gas Delivery (bcm/yr)	47.74	22.11	15.13	10.49	32.60
IIC ($)	2,572,218,329.69	1,077,388,856.25	501,175,146.27	1,423,654,327.18	2,071,043,183.42

Table 8 enumerates the different capital cost elements of the other five gas pipeline route options. The combination of all the possible gas pipeline routes obviously has the highest initial investment costs, which is around $2.57 billion. The combination of BRO and NRO (BNRO) is the second most expensive option with $2.07 billion as its IIC. The combination of BRO and SRO (BSRO) as earlier presented is less expensive than the BNRO, which costs $1.15 billion. This means among the three options that combine two different possible routes options, the BSRO is less expensive, and this is attributed to the low distance of the SRO segments. Looking at the possible single routes options, The SRO is less expensive than BRO and NRO as it was estimated to cost $501 million. The most expensive single route option is the NRO, which was estimated to cost $1.42 billion.

The weighted average cost of capital for both options are assumed to be the same, because it is the same business environment and proportion of the capital sources will be the same, and the alternative or comparative investment return is the same risk free rate. So the WACC will be constant in all the scenarios. Similarly, the 2.5% depreciation rate is applied using straight line depreciation method, after deducting the SV of the pipelines. All other procedures applied in the case of BSRO pipelines are applied in the other possible route options, and summary of their costs and benefits are presented in table 16 below. Availability rate of 80%, gas transportations cost of $0.80/Mcf and tax rate of 30% are equally applied.

Table 9: Costs and Benefits of other gas pipeline routes

BSRO Pipeline system	BSRO	All pipelines route options	BNRO	BRO	SRO	NRO
Capital cost ($)	1,148,564,002.52	2,572,218,329.69	2,071,043,183.42	1,077,388,856.25	501,175,146.27	1,423,654,327.18
Equity ($)	459,425,601.01	1,028,887,331.88	828,417,273.37	430,955,542.50	200,470,058.51	569,461,730.87
Debt ($)	689,138,401.51	1,543,330,997.81	1,242,625,910.05	646,433,313.75	300,705,087.76	854,192,596.31
Amortization cost ($)	116,690,570.44	261,329,471.86	210,411,618.28	109,459,394.46	50,917,853.58	144,638,901.43
Depreciation rate	2.50%	2.50%	2.50%	2.50%	2.50%	2.50%
Depreciating Value ($)	731,368,297.51	1,637,905,189.87	1,318,773,114.80	686,046,273.29	319,132,075.08	906,536,892.36
Annual Depreciation ($)	18,284,207.44	40,947,629.75	32,969,327.87	17,151,156.83	7,978,301.88	22,663,422.31
Annual O and M cost ($)	22,971,280.05	51,444,366.59	41,420,863.67	21,547,777.12	10,023,502.93	28,473,086.54
Annual Gas delivery (bcm)	37.25	47.74	32.60	22.11	15.13	10.49
Annual Gas delivery in Mcf	1,315,329,027.25	1,685,846,395.34	1,151,376,875.70	780,826,340.63	534,469,519.63	370,550,535.07
Actual Gas delivery (Mcf)	1,052,263,221.80	1,348,677,116.27	921,101,500.56	624,661,072.51	427,575,615.70	296,440,428.06
Annual Revenue ($)	841,810,577.44	1,078,941,693.01	736,881,200.45	499,728,858.00	342,060,492.56	237,152,342.45
Net Annual Revenue ($)	818,839,297.39	1,027,497,326.42	695,460,336.78	478,181,080.88	332,036,989.64	208,679,255.90
Gross tax payments ($)	245,651,789.22	308,249,197.93	208,638,101.03	143,454,324.26	99,611,096.89	62,603,776.77
Tax benefit from depreciation ($)	5,485,262.23	12,284,288.92	9,890,798.36	5,145,347.05	2,393,490.56	6,799,026.69
Tax Payable ($)	240,166,526.99	295,964,909.00	198,747,302.67	138,308,977.21	97,217,606.33	55,804,750.08
Annual Cash Flow ($)	578,672,770.40	731,532,417.42	496,713,034.11	339,872,103.67	234,819,383.31	152,874,505.83
Additional cash flow in final year						
Salvage value ($)	417,195,705.00	934,313,139.82	752,270,068.63	391,342,582.96	182,043,071.19	517,117,434.82
Tax on selling at salvage value ($)	125,158,711.50	280,293,941.95	225,681,020.59	117,402,774.89	54,612,921.36	155,135,230.45
Net Gain ($)	292,036,993.50	654,019,197.87	526,589,048.04	273,939,808.07	127,430,149.83	361,982,204.37
NPV ($)	2,426,384,322.79	1,947,786,895.83	998,262,864.07	1,022,543,778.19	949,524,031.76	-478,505,650.40
IRR	50.38%	28.44%	23.98%	31.55%	47%	11%
Discounted payback period (yrs)	2.60	5.62	7.49	4.80	2.83	-

Table 9 lists all the costs and benefits of the other gas pipelines routes. The NPV of the BSRO pipelines is the highest, which is approximately $2.4 billion. This means that, the BSRO pipelines have higher economic benefit than other options. The next must viable option is the all gas pipeline routes option, because it has the second highest NPV, which is approximately $1.9 billion. The third most viable option is the BRO pipelines which has an NPV of approximately $1 billion. The fourth and fifth most viable options are the BNRO pipelines and SRO pipelines which have an NPV of approximately $998 million and $950 million respectively. The least and unviable option is the NRO pipelines which have the negative NPV of $479 million, which means the pipelines are not viable. The hierarchy of the viability of these projects based on NPV are presented in figure 5 below.

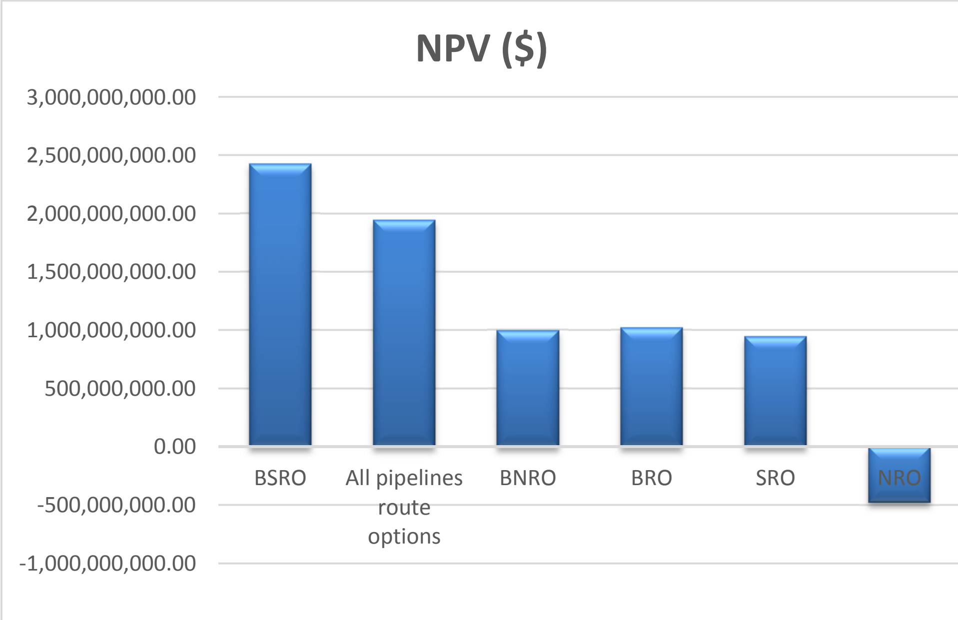

Figure 5: Graphical presentation of the NPV of the gas pipeline options

Figure 5 shows the hierarchy of the viability of all the gas pipeline route options based on NPV, showing the BSRO as the most viable option, followed by other gas pipeline routes in the following order: combination of all the pipeline route options, BRO, BNRO, SRO, and NRO as already discussed above. The NPVs of all the gas pipelines options are positive except for the NRO pipelines, which means they are all viable except the NRO pipelines.

Similarly, the IRR of all the investment options except for the NRO pipelines are higher than the discount rate (16.15%), which is considered the hurdle rate, the minimal rate of return for all the project options, which means the IRR is also showing that all the gas pipeline options are viable except the NRO gas pipelines. Using the IRR in ranking the project options, the hierarchy changed, where the BSRO pipeline maintained its positions as the most viable with the highest IRR of 71%. The graphical presentation of this hierarchy is presented in figure 6.

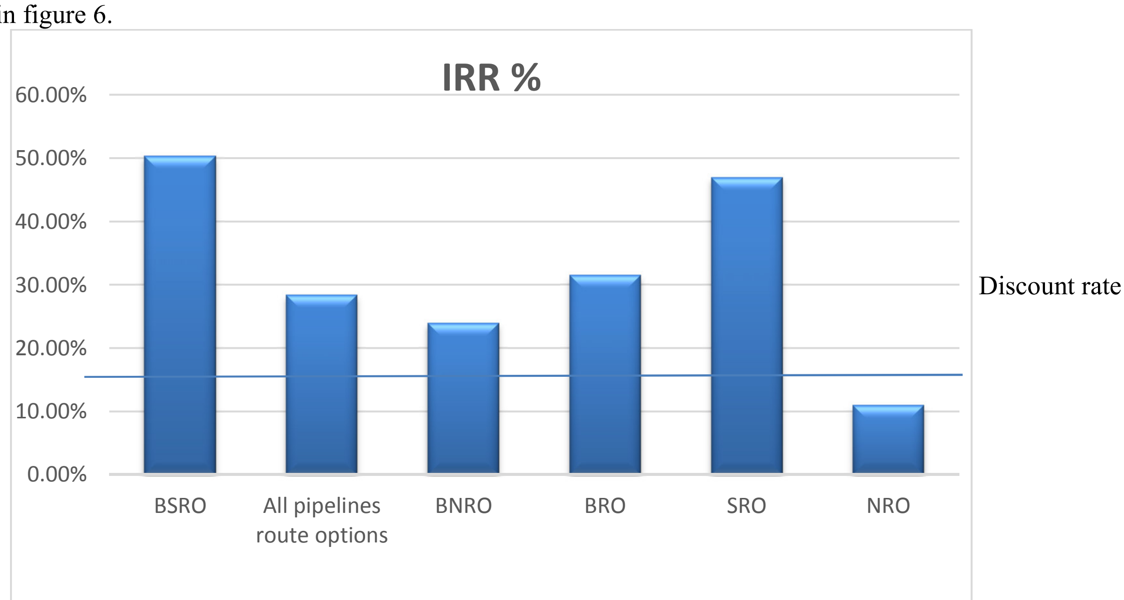

Figure 6: Graphical presentation of the IRR of the gas pipeline options

Figure 6 shows the IRR of the gas pipelines, where the BSRO has the highest IRR of 50.38%. The second highest IRR is that of SRO pipelines (47%), which were ranked fifth going by the NPV. The third most viable option going by IRR are the BRO pipelines that have an estimated IRR of 31.55%. All gas pipeline routes option and BNRO pipelines are ranked the fourth and fifth by the IRR, which have an IRR of 28.44% and 23.98% respectively. The least viable option is the NRO pipelines, which have IRR rate of 11%. All the IRR were above the discount rate expect the IRR of NRO pipelines.

The IRR shows the rate of return where the NPV equals to zero, this means that the BSRO and SRO has the potential of offering higher investment return at breakeven. In other word, the IRR can be viewed as the maximum percentage rate that can be earned on each dollar invested at a period [68]. The two methods have discrepancy in ranking the projects, which is possible because of a possible difference in the size of the investment, or timing of the positive net cash flows [69]. In this scenario, the discrepancy is attributed to the differences in the size of the businesses as well as the size of the cash flows, as the NPV accounts for difference between discounted cash flows and initial investment, which means higher initial investment might cause lower NPV, and higher cash flows can return higher NPV, while the IRR estimates the rate of return at which the discounted cash inflows will equate the initial cash outflows. Therefore, both techniques might have different ranking order. However, some recommended to go by NPV method, as the IRR rate is an arbitrary rate, which signals the maximum possible rate of rate, which might not be attainable given the business scenarios [70] [71] [72]. IRR favours investments that return initial investment quicker, which makes it more agreeable to the Payback period method [68].

The Payback period ranking is similar to the ranking of the IRR, BSRO pipelines have the lowest payback period of 2.60 years, and then BRO pipelines have payback period of 4.80 years. Others have payback period of 2.83, 5.62 and 7.49 years for SRO, all pipeline route option and BNRO pipelines respectively. NRO pipelines are not recoverable, so their initial investment costs cannot be recovered within the operational period. All the three accounting indicators suggest that BSRO pipelines are the most viable option

Joining the ranking outcome of NPV, IRR and Payback period, figure 7 illustrates the heights of the ranking of these investments

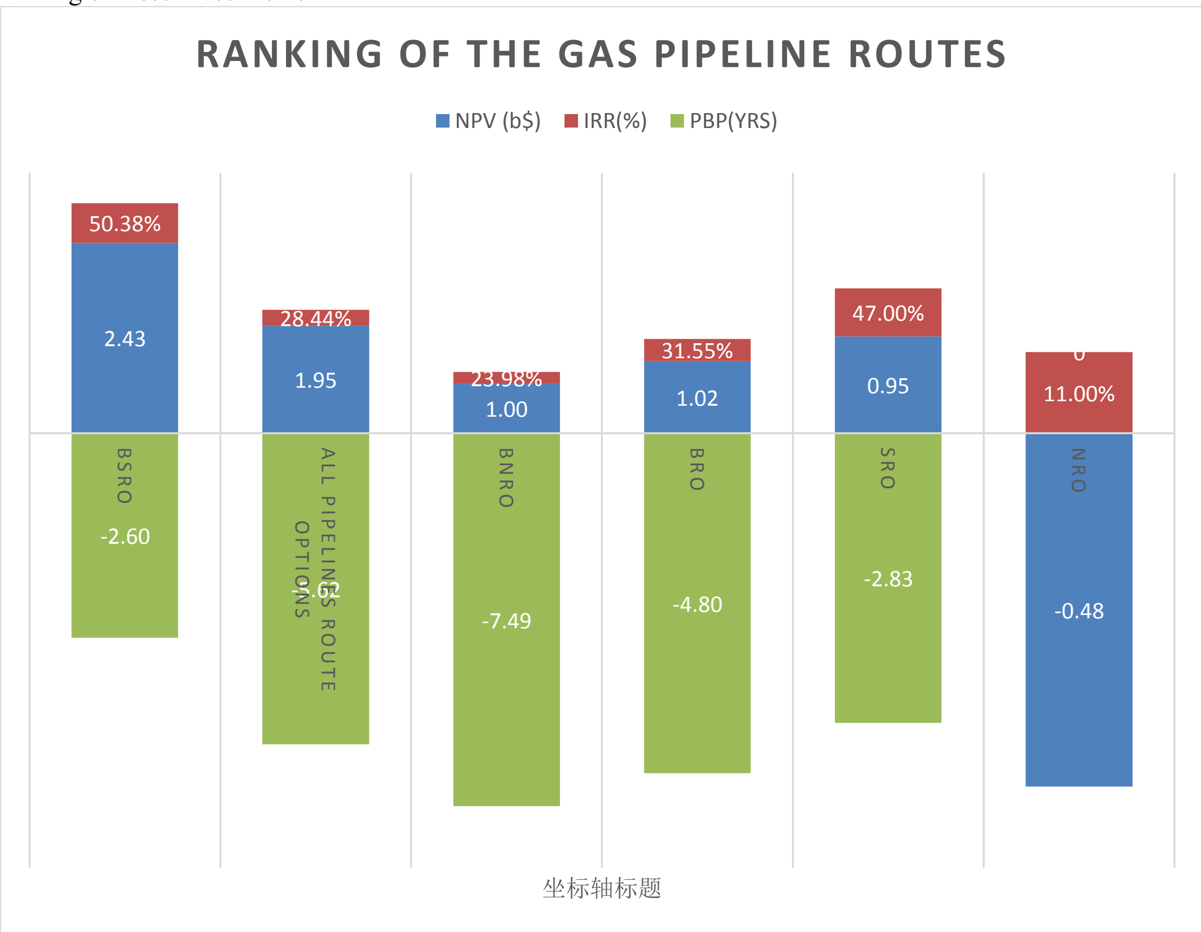

Figure 7: Ranking of the gas pipeline route options using the three accounting indicators

From figure 7, the top two business investments going by the top height above zero when combing the effects of IRR and NPV together are; BSRO and all gas pipelines option. Considering the green bar, which is the payback period and is expected to be shorter for the most viable option, the BSRO pipelines still have shorter height of -2.60, which means it has shorter payback period and more preferred than all the other options. NPV is largely the most considerable method compare to other techniques as explained earlier as it accounts for exact magnitude of the return and it is more precise estimate of the returns than the IRR [71] [72]. Relying on one criteria may not reflect the effect of other criteria in the judgement, which could be influential in ranking the projects.

Therefore, to harmonise the different ranking positions based on these criteria, the ranking positions are added and the pipeline with the lowest ranking position will be the most viable. The lowest point matters because lower points mean most viable, for example, the most viable option at a time is always ranked as number 1. Table 10 shows the ranking position of each of the gas pipeline options.

Table 2: Ranking positions based on the three profit indicators

Pipelines	Ranking position
BSRO	
NPV	1
IRR	1
PAYBACK PREIOD (YRS)	1
Points	**3**
All possible pipeline routes option	
NPV	2
IRR	4
PAYBACK PREIOD (YRS)	4
Points	**10**
BNRO	
NPV	4
IRR	5
PAYBACK PREIOD (YRS)	5
Points	**14**
BRO	
NPV	3
IRR	3
PAYBACK PREIOD (YRS)	3
Points	**9**
SRO	
NPV	5
IRR	2
PAYBACK PREIOD (YRS)	2
Points	**9**
NRO	
NPV	6
IRR	6
PAYBACK PREIOD (YRS)	6
Points	**18**

Table 10 shows the different ranking positions of each of the pipeline options as indicated by the three accounting methods. For each method, ranking was made, with the most viable being the number 1. Summing the ranking positions for each project, the BSRO pipelines have the lowest ranking points, which is 3. This is because it was ranked 1st in all the three accounting indicators. This makes it the most viable option among the six options based on the harmonised ranking positions. The second most viable options based on this ranking are the BRO and SRO pipelines, which both have the harmonised ranking points of 9. All gas pipeline options and BNRO are ranked 3rd and 4th respectively, with the harmonised ranking points of 10 and 14 respectively. The Least and unviable is the NRO pipelines, which has the harmonised ranking point of 18.

Therefore, BSRO pipelines are the most viable option among the six projects. All the project options except the NRO pipelines were viable at the base scenario. It is recommended not to consider this option (NRO) alone, even in the future, the best recommendation is to combine it with the BRO pipelines, since BRO pipelines are likely to be constructed soon, it is advisable to include the NRO pipelines. This academic finding justifies the intention of the government to consider investing on the BSRO pipelines.

However, in terms of coverage and ability to supply more gas to more locations, the all gas pipeline option is more recommendable. The all gas pipeline option covered the whole country, and this enables spread of potentials for gas development sites and job creations. The spread of the gas power turbines can be well achieved if all the gas pipeline options are considered. Concentration of industries in the south has caused migration from the north, and making the northern economy less active. This is because access to industrial inputs are easier in the south as the oil and gas production take place in the region. The electricity shortages was also partly attributed to the low transmission capacity and transmission losses. Around 20% of the existing transmission capacities are not operational [73], and 8.05% of electricity generated is lost in the process of transmission [74]. The over reliance on the transmission networks can be highly reduced if the all gas pipeline routes option is constructed ,and as a result, more distributed gas power turbines can be constructed, which can be connected to the distribution lines. This will enhance sub-regional power generations and investment in distribution lines, and will motivate establishment of industries across the country, and avoid unnecessary migration of labour forces. This will also facilitate spread of higher productivity of the industrial, commercial and residential sectors in every region as the access to natural gas is equally provided. The value addition as a result of the wide spread of the gas supply, which can be achieved through all the gas pipeline route option can offset the lower viability of the option compare to the BSRO pipelines.

The all gas pipeline route option is equally viable, and its NPV is not much lower than the BSRO pipelines, its IRR is 28.44%, and has payback period of 5.62 years, as such, it is worth considering. Therefore, the all gas pipeline routes option is highly recommended. If all the gas pipelines routes are considered together, the NRO pipelines will not be singled out, which if singled out, the NRO pipelines will be unviable.

4. Summary and Conclusion

The research studied how viable the new gas pipeline options are in Nigeria so as to guide for optimal investment decisions. The new pipelines are essentials as they help to enhance utilization of vast natural gas reserves in the country and stimulate latent energy demand and thereby derive economic advantage and address the country's energy demand concerns within its territory. Since Nigeria has the advantage of not have to import natural gas, the research identified three major gas development projects that Nigeria can develop to fully utilize its natural gas reserves within its territory. The key project that is key to achieving the objective of the country's gas master plan (ensuring domestic gas utilization in the country) is domestic gas pipelines. Consequently, this study analysed the costs and benefits of six possible domestic gas pipelines route options on the scale of the total investment costs, gas delivery as well as costs and benefits using NPV, IRR and Payback period, and found that BSRO pipeline option is the optimal pipeline routes combination. However, in terms of coverage and ability to supply more gas to more locations, all gas pipeline route option is more recommendable, which is the third most viable among the six options. The summary of these economic indicators for each of the gas pipeline options are presented in table 11.

Table 31: Economic indicators of the gas pipelines routes options

Indicator	BSRO	All pipelines route options	BNRO	BRO	SRO	NRO
Capital cost ($)	1.15 billion	2.57 billion	2.07 billion	1.08 billion	501.18 million	1.42 billion
Gas Delivery (bcm/yr)	37.25	47.74	32.60	22.11	15.13	10.49
NPV ($)	2.43 billion	1.95 billion	998 million	1.02 billion	950 million	-479 million
IRR	50.38%	28.44%	23.98%	31.55%	47%	11%
Discounted payback period (yrs)	2.60	5.62	7.49	4.80	2.83	-

The total investment cost of the BSRO pipelines option was estimated to be $1.15 billion and its annual gas delivery was estimated at 37.25 billion cubic metres of natural gas. The NPV, IRR and payback period of the BSRO pipelines option were estimated to be approximately $2.43 billion, 50.38% and 2.60 years respectively. It was discovered to have the potential of supplying gas directly to approximately 50 million populations as it cuts the country into two parts, supplying the gas directly to extreme northern part of the country from the Niger Delta. These indicators have found the BSRO pipeline options to be more economically viable compare to other pipelines route options. Using the harmonised ranking points from each of these indicators, the BRO and SRO pipelines option were ranked second most viable.

However, in terms of coverage and ability to supply more gas to more locations, the all gas pipeline route option is more recommendable. The route option that combined all pipelines routes was ranked 3rd most viable, which has the estimated NPV of $1.95 billion, IRR of 28.44%, payback period of 5.62 years and can supply gas up to 100 million population. Therefore, Nigerian government is encouraged to consider constructing the whole gas pipeline route options, and private investors should be encouraged to invest in the gas pipeline constructions. All the gas pipeline options are viable, the only option that is not viable is the NRO pipelines option, and it is recommended not to consider this option alone, even in the future, the best recommendation is to combine it with the BRO pipelines option. This empirical finding justifies the decision of the Nigerian government to opt for the construction of the BSRO pipelines, but it is recommended to consider all the pipeline options at a time.

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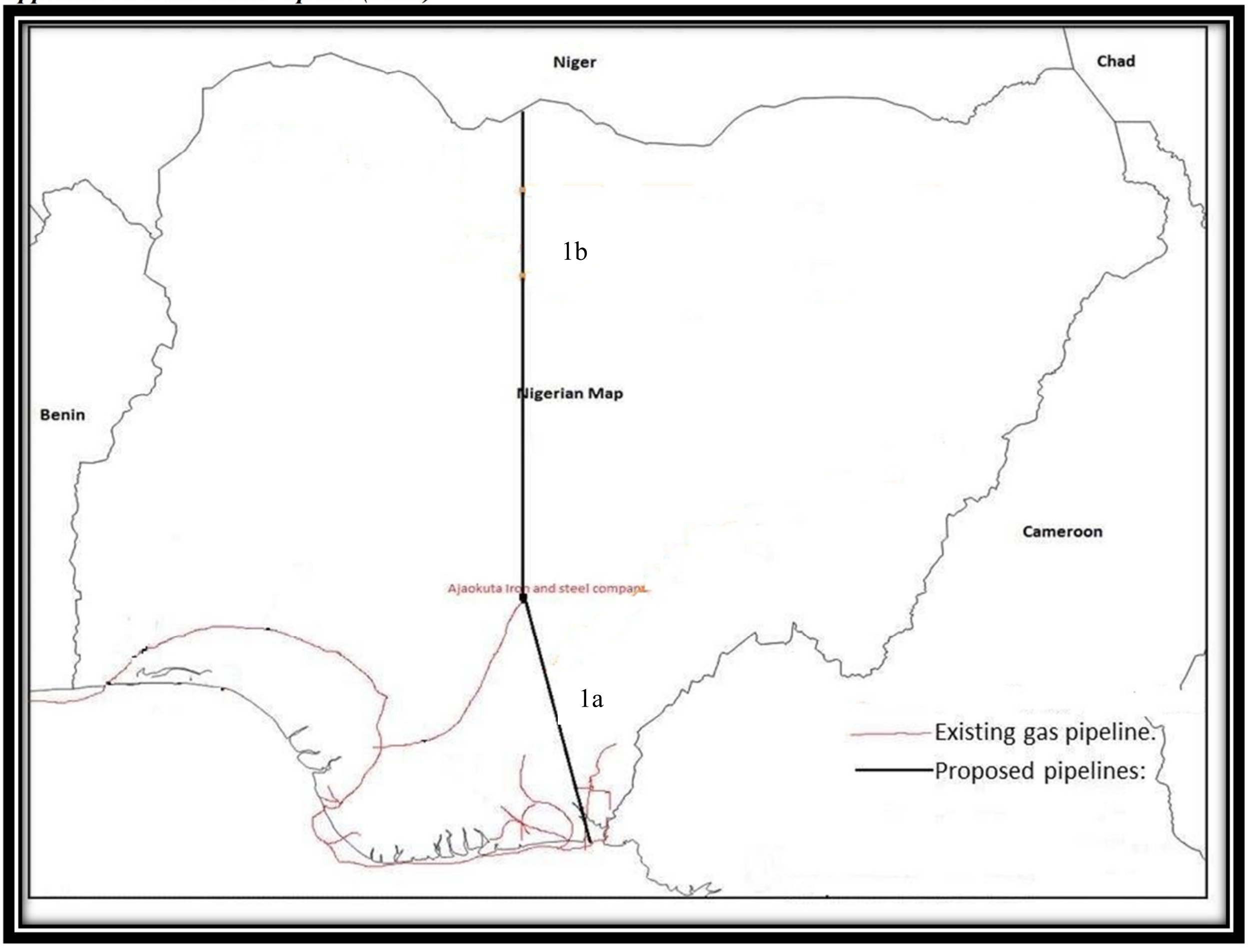
APPENDICES

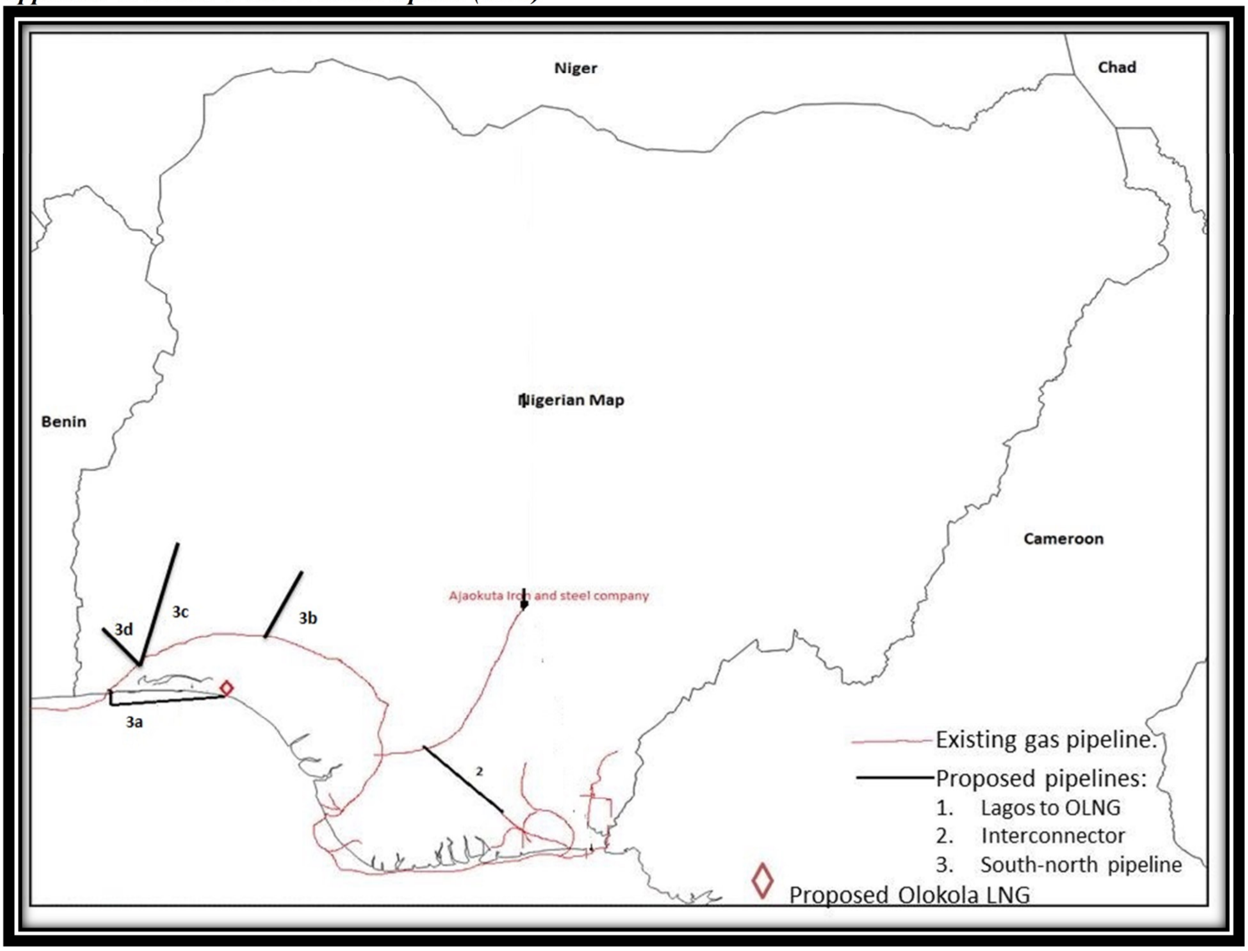
Appendix A: Base Route Option (BRO)



Appendix B: Specification of the BRO

Pipeline	Diameter	Length (km)
1. South-North (Trunk Line):		
1a Calabar to Ajaokuta	56”	490
1b Ajaokuta to Kaduna	48”	495

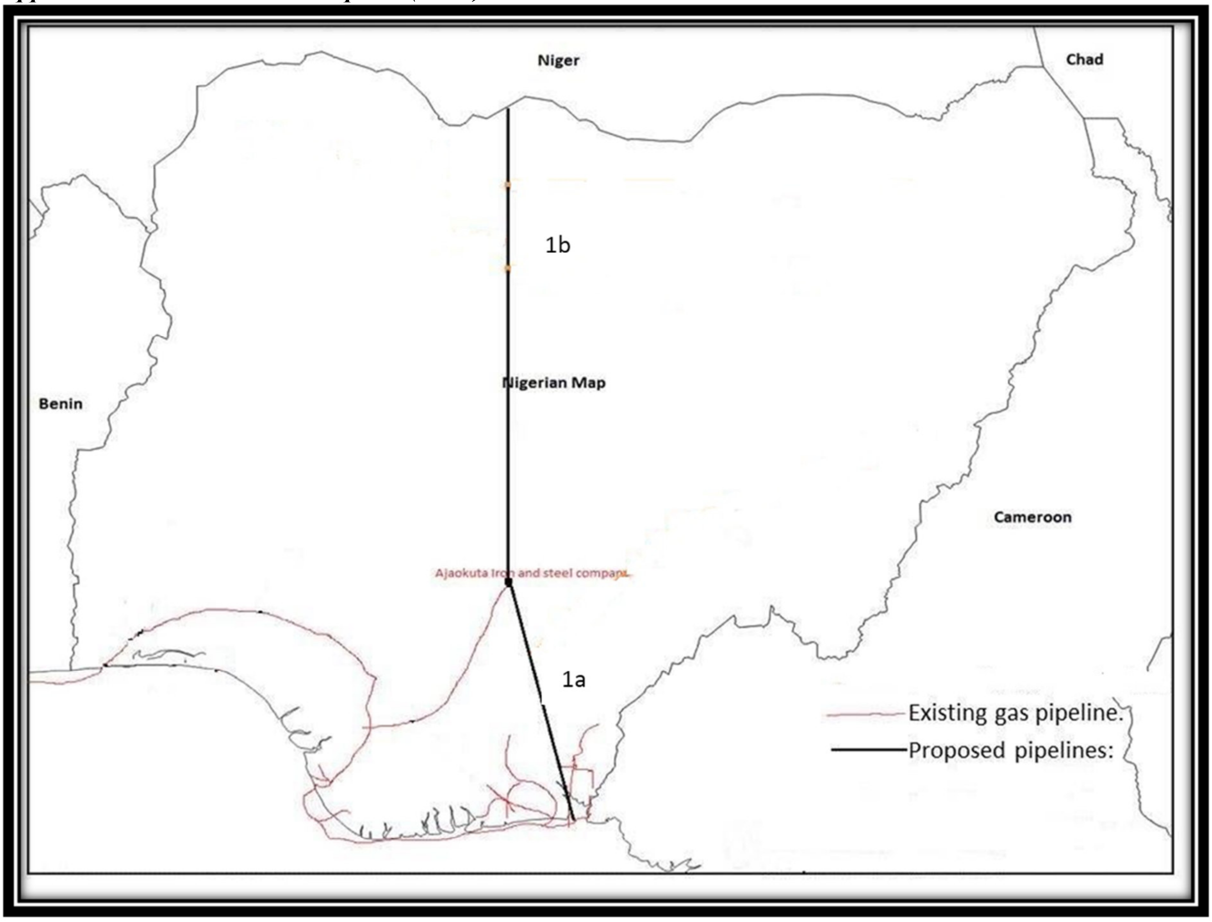
Appendix C: South-Western Route Option (SRO)



Appendix D: Specification of SRO

Pipeline	Diameter	Length (km)
2. Interconnector: Obiafu-Oben Node	42”	100
2. Four segments of West-Escravos extensions		
3a: Warri-Shagamu	42“	200
3b: Ore-Ondo-Ekiti	24”	125
3c:Shagamu-Ibadan-Osun-Jebba	24“	321
3d: Shagamu -Papalantro	16“	40

Appendix E: Northern Route Option (NRO)

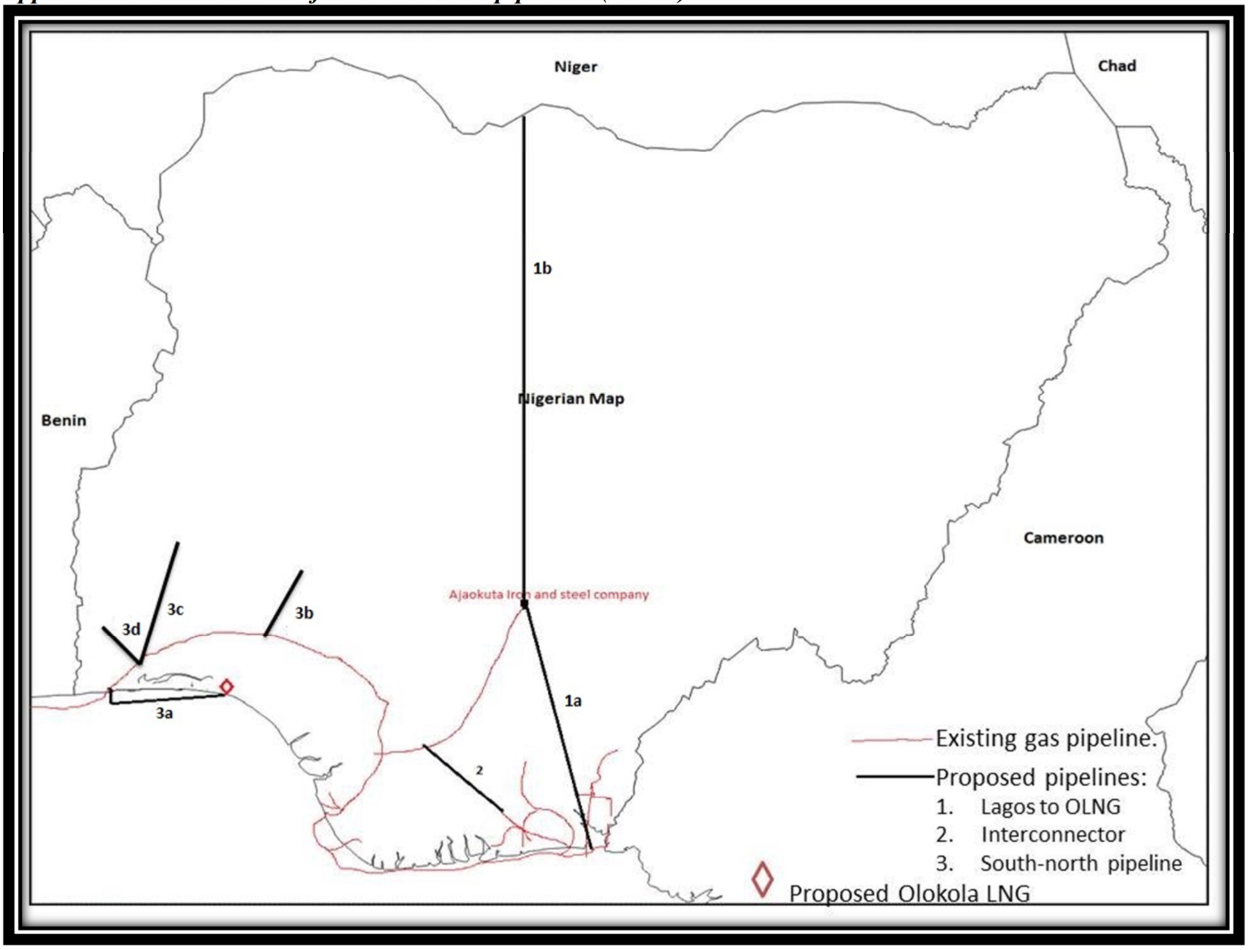


*NRO cannot exist without the BRO, so its business model is established on the assumption that the BRO is already constructed.

Appendix F: Specification of NRO pipelines

Pipeline	Diameter	Length (km)
4. Future potential pipelines:		
4a: Enugu-Makurdi-Yola	24	874.8
4b:Kaduna-Jos-Gombe	24	501.3
4c: Kano-Maiduguri	24	593.2
4d: Zaria-Funtua(then to Katsina)-Gusau-Sokoto-Birnin Kebbi	24	768.3

Appendix G: Combination of BRO and SRO pipelines (BSRO)



Appendix H: Specification of the combination of BRO and SRO pipelines (BSRO) [1]

Pipeline	Diameter	Length (km)
1. South-North:		
1a Calabar to Ajaokuta	56”	490
1b Ajaokuta to Kaduna	48”	495
2. Interconnector: Obiafu-Oben Node	42”	100
3. Four segments of West-Escravos extensions		
3a: Warri-Shagamu	42“	200
3b: Ore-Ondo-Ekiti	24”	125
3c:Shagamu-Ibadan-Osun-Jebba	24“	321
3d: Shagamu -Papalantro	16“	40

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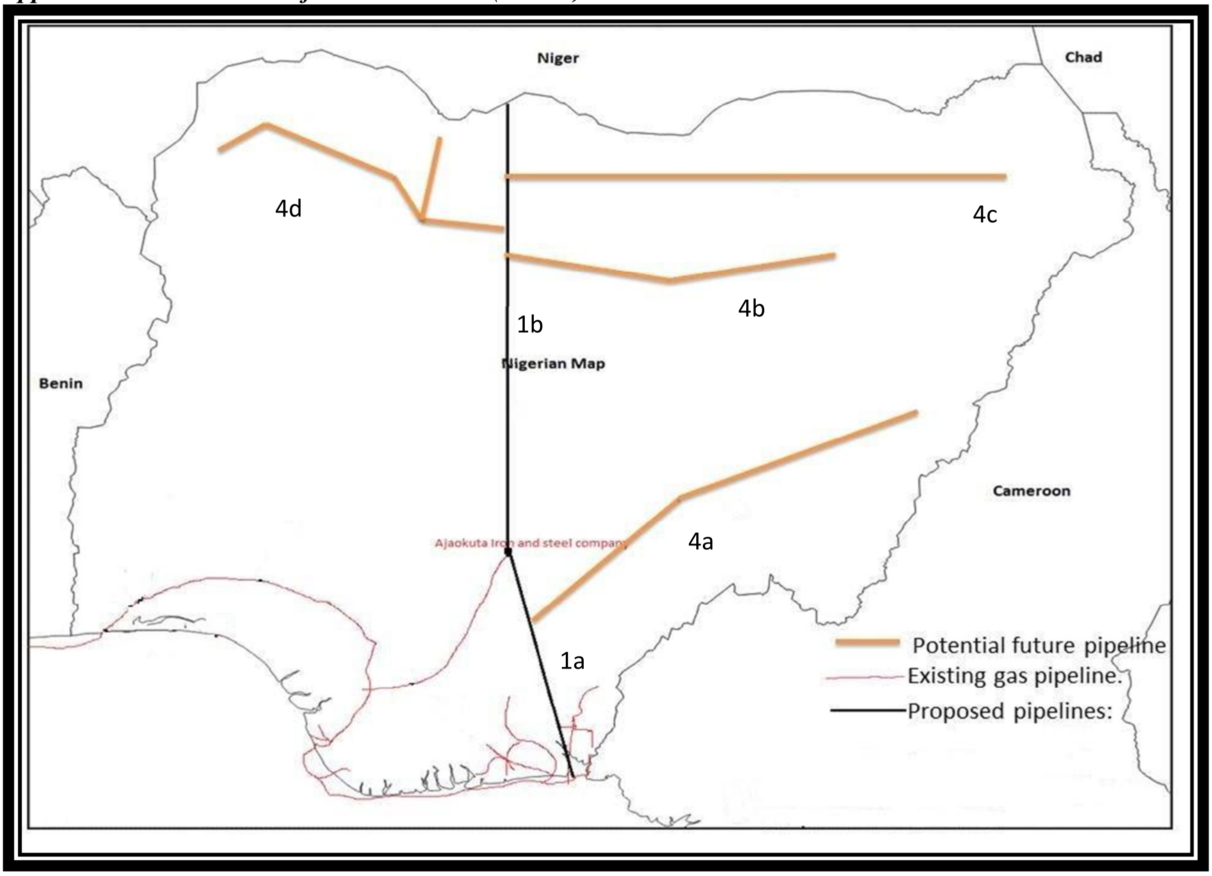
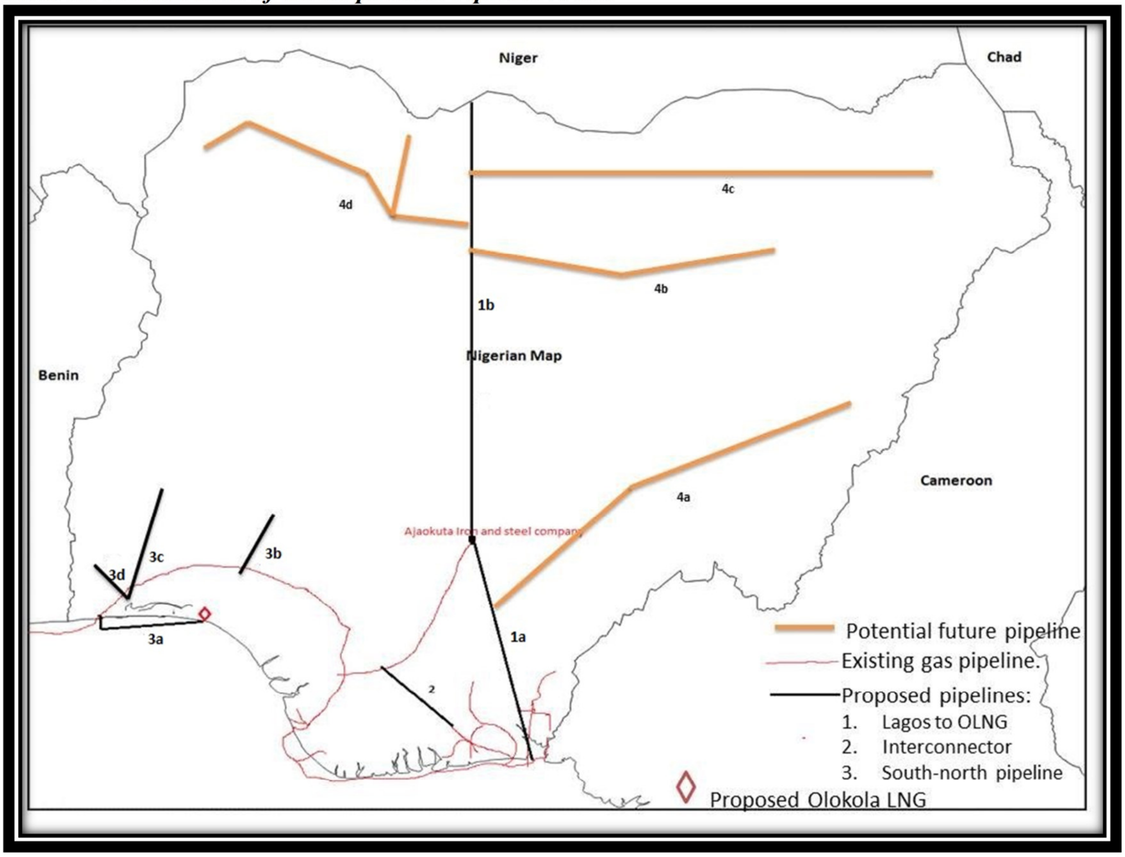
Appendix I: Combination of BRO and NRO (BNRO)



Appendix J: Specification of the combination of BRO and NRO (BNRO)

Pipeline	Diameter	Length (km)
1. South-North:		
1a. Calabar to Ajaokuta	56	490
1b. Ajaokuta to Kaduna	48	495
4. Future potential pipelines:		
4a: Enugu-Makurdi-Yola	24	874.8
4b:Kaduna-Jos-Gombe	24	501.3
4c: Kano-Maiduguri	24	593.2
4d: Zaria-Funtua(then to Katsina)-Gusau-Sokoto-Birnin Kebbi	24	768.3

Appendix K: Combination of all the possible Pipeline routes



Appendix L: Specification of Combination of all the possible Pipeline routes [1] [16]

Pipeline	Diameter	Length (km)
1. South-North:		
1a Calabar to Ajaokuta	56”	490
1b Ajaokuta to Kaduna	48”	495
2. Interconnector: Obiafu-Oben Node	42”	100
3. Four segments of West-Escravos extensions		
3a: Warri-Shagamu	42“	200
3b: Ore-Ondo-Ekiti	24”	125
3c:Shagamu-Ibadan-Osun-Jebba	24“	321
3d: Shagamu -Papalantro	16“	40
4. Future potential pipelines:		
4a: Enugu-Makurdi-Yola	24”	874.8
4b:Kaduna-Jos-Gombe	24”	501.3
4c: Kano-Maiduguri	24”	593.2
4d: Zaria-Funtua(then to Katsina)-Gusau-Sokoto-Birnin Kebbi	24”	768.3