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Analysis of Levelised Gas Transportation Cost in Nigeria

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Abstract—**Nigeria is committed toward developing its Natural Gas energy subsector in order to address the energy trilemma in the country; as a result, Nigerian Gas master plan proposes new gas pipeline. The paper analyzes the life cycle cost (using Shahanon Pipeline Cost Model) of the Gas pipeline networks (FRA) proposed in the plan, and introduces additional and separate pipeline system (SRA) for comparison. SRA pipeline represents 67% increase on the FRA pipeline capacity, 115% increase on the FRA's capex and 152% increase in kilometer distance, and as a result, led to increase in Levelised Gas Transportation Cost (LTC) by 25%. This justifies that higher increase in capacity results to relatively modest increase in LTC. The effect of adjusting pipeline capacities on LTC was also observed, and LTC was discovered to fall continuously as capacity increases. The study concluded that, it is more economical to have large gas pipeline capacities and operate pipelines at their full capacities, as more capacity leads to low LTC. Therefore, it is advisable if Nigerian government will consider the second alternative route as it covers most of the demand potential areas and has relatively low LTC. Moreover, investing in the SRA will also serve long-term investment needs, as all potential demand areas are covered.**

Keywords— Levelised Gas Transportation Cost (LTC), First Route Alternative option (FRA), Second Route Alternative option (SRA)

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I. Introduction

Nigeria has the largest gas reserve in Africa and contributes 2.5% of the global share of proven gas reserves, yet it is the second worst country in terms of gas flaring globally. [1] The National Oil Company of the country is determined to make the natural gas sector as much competitive as the oil sector. The oil sector is the main stay of the country's economy and contributes almost 100% of its total foreign earnings. Nigeria has over 120 Trillion Cubic Meters of Natural gas reserves with 50/50 distribution ratio between associated and none associated gas. [2] In order to develop the associated and the stranded gas reserves in the country, some gas development infrastructures have to be developed, primarily gas pipelines. The National Oil Company in the country, which is known as Nigeria National Petroleum Corporation (NNPC) developed a gas master plan with proposed gas pipeline systems that will convey natural gas from oil and gas rich region to other parts of the country where huge energy demands are not met.

This paper studies the proposed gas pipeline in the Nigerian gas master plan to estimate its total lifecycle cost, volume of gas to be transported and the levelised cost of transporting each volume of the gas along the system. For comparison and optimization of investment in the gas sector, additional gas system is proposed to assess the economic viability of the two systems. Therefore, this paper will consider two alternative pipelines routes for transporting gas from the Niger Delta area (the Nigerian oil rich region) to major expected gas demand areas within Nigeria. First route alternative is adopted from the Nigerian gas master plan, and the second route is hypothesized to link major locations with high-energy demand potentials. These areas were selected by considering the strategic location of cities with high population density proximate to other cities.

The aim is to develop models that will estimate the investment costs and levelised cost of transporting gas on the two alternative gas transmission systems. The paper will not consider any cost 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. Estimation of capital requirements for these two options will be presented. Capital cost of transmission pipelines consists of at least 80% of its total cost [3]. Figure 1 and 2 as well as table 1 and 2 present the geographical routes of these proposed pipelines and their specifications in terms of capacity, pressure level, diameter, number of compressor stations and distance respectively.[4]

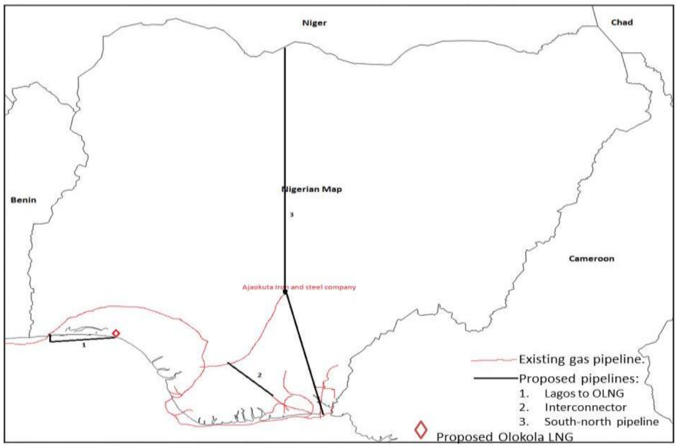

Figure 1: first route alternative (from Nigerian gas master

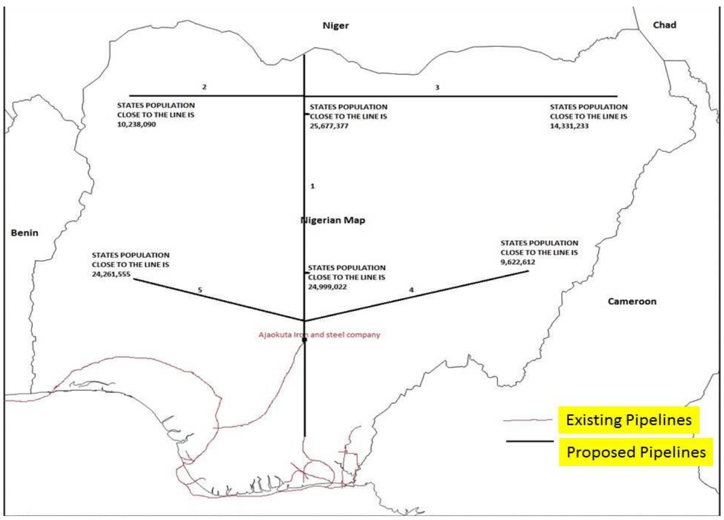

Figure 2: second route alternative (hypothesized option)

Pipeline	Diameter	Capacity/yr	Pressure (bar)	Length (km)	Compressors 5000HP (At each 64 km)
1. Lagos to OKLNG	81.28 cm	$10 \times 10^9 m^3$	60	17.22	3
2. Interconnector	81.28 cm	$10 \times 10^9 m^3$	60	192.48	3
3. South-North	81.28 cm	$10 \times 10^9 m^3$	60	954.62	15

Table 2: Specification of First route Alternative (FRA)

Pipeline	Diameter	Capacity/yr	Pressure (bar)	Length (km)	Compressors 5000HP (At each 64 km)
1.Potharcourt-Katsina	81.28 cm	$10 \times 10^9 m^3$	60	1,112	17
2.Kano -Sokoto	81.28 cm	$10 \times 10^9 m^3$	60	477	7
3.Kano-Maiduguri	81.28 cm	$10 \times 10^9 m^3$	60	505.76	8
4.Lokoja to Jalingo	81.28 cm	$10 \times 10^9 m^3$	60	521.68	8
5.Lokoja to Ibadan	81.28 cm	$10 \times 10^9 m^3$	60	317.93	5

Table 1: Specification of the second route alternative (SRA)

II. Levelised Cost of Gas Transportation in Nigeria.

According to EIA, [5] levelised cost of gas transportation is the discounted (present value) of the average cost of transmitting a gas volume from one place to another over a period. It is the total cost of constructing and operating a gas pipeline per unit of gas transmitted through a pipeline over its economic life cycle. That is to say, how much it will cost to transport a unit of gas volume of gas from one point to another for a period. This paper will analyze how much US dollars will be spent to transport one billion cubic meters (bcm) of natural gas for the period of 40 years for the two proposed gas pipeline systems. This will help the gas pipeline operator to have an idea of how much to charge for using the gas pipeline per certain volume of gas, and subsequently estimate the profit to be derived.

A. *Methodology*

Levelised Cost of gas transportation and the expected cost of building the proposed gas pipelines in the country will be analyzed using levelised cost of transportation from the Niger Delta Region to far northern region. Levelised costs of two alternative gas routes will be measured by dividing the sum of investment costs required to build each of the two possible pipeline routes by the quantity of gas to be transported through each of the pipelines over a period of forty years, which is assumed to be the economic life of the systems. This will give the Nigerian Gas Company (NGC), the Nigerian National Petroleum Corporation (NNPC) as well as the prospective private investors the idea of how much will be required to transport each billion cubic meters of natural gas for each of the two alternative gas routes from the oil rich area to the market place for the specified period. The aim is to guide the government and investors on which of the options is best in terms of low investment cost, profit return and the levelised cost of transporting the gas.

The formula for estimating the levelised total costs (LTC) of gas transportation is presented below, which is adopted from Chyong et al (2010)[6]:

$$LTC = \frac{\text{PV of total life cycle cost}}{\text{PV of the cummulative gas volumes conveyed over the lifetime of the pipeline}}$$

Where:

LTC is the Levelised total cost of transporting the natural gas. Total life cycle costs will consist of the following equations (1-5):

Equation 1

$$Investment\ costs = E(CCP) + E(CCMS) + other\ costs$$

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.

$$E(CCP) = ICC_P \times UCF_P$$

Where, ICC_P stands for the initial cost of constructing/laying down the gas pipeline and UCF_P stands for the uncertain costs factor for constructing the gas pipeline.

$$E(CCMS) = ICC_C \times UCF_C$$

Where, ICCc stand for Initial cost of compressor stations and UCF is the uncertain factors associated with the cost of compressor stations. Uncertain factors accounts for the possibility of variation (higher or lower value) in the estimated fixed cost of constructing the pipeline and the compressor stations (UCF_P and UCF_c). It is assumed here to vary randomly between 0.9 and 1.3, and 1 and 1.4 for costs of constructing the pipeline and the compressor stations respectively. The choice of 0.9 and 1.3 for the costs of constructing the pipeline was to accommodate the possibility of 10% discount and 30% inflation of the initial costs of constructing the pipeline. For the costs of constructing compressor stations, we assume no discount (100%) and possibility of 40% inflation. These assumptions were adopted from the work of Barinov (2007) who studied the possibilities and reasons for discounts and inflations of initial costs of constructing gas pipelines and compressor stations. [7] According to Barinov, "Price surge are caused by changes in the design of hydro-technical constructions, refinement and updating of engineering solutions for enhancing of the system reliability and environmental safety, provision of necessary infrastructure for the port. Cost overrun was also combined with a considerable cost cut with respect to some cost items". Other costs include the commitment fees that an investor pays to the lender. This is in case the money for constructing the pipeline is to be borrowed from an external source. In Nigerian situation, since the gas pipeline is hypothesized to be owned and controlled by the government, then it has the option of either using its own reserves or borrowing abroad, depending on the convenience of the government.

Depreciation and taxation are also accounted. Straight-line depreciation method is assumed. Straight-line depreciation method is the accounting way of calculating the devaluation of an item at a fixed rate over a long period of time. 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. It is related to taxation, because corporate tax rate is charged against the value of an asset. Usually companies deliberately over depreciate their assets in order to reduce their tax burden.[8] The higher the asset values the higher the tax payment. 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. Therefore it will be deducted. The benefit is derived by calculating the difference (reduction) of the tax payment because of the pipeline depreciation. Since the proposed gas pipeline is within Nigerian territory, the complexity of using different corporate tax rates will not arise. It is also assumed that there would not be decommissioning cost and no scrap value as our motive is to reveal the economic returns for the period of the pipeline operation. This is attainable since the technical life span of the pipeline is much longer than its depreciation period. The equation for the cumulative annual depreciation tax benefit is presented below, which will be deducted from the overall equation of the present value of the total life cycle of the gas pipeline. N=40 years.

Equation 2

$$PV\ of\ tax\ benefit = -\sum_{n=1}^{N} \frac{DEPRECIATION_N}{(1 + DISCOUNT\ RATE)^N} \times \text{Tax Rate}$$

Annual operating and maintenance costs (O and M) have to be considered even though the pipeline is not in operation, but an assumption can be made base 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 the O and M costs annually [9-11]. O and M costs consists of costs of labour, supervision, energy, telecommunication, miscellaneous, compression costs etc. The following equation is for the present value of the O and M costs for forty years, which will be added to the main equation of the total life time cost of the pipeline. 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%.

Equation 3

$$Present\ value\ of\ O\ and\ M\ costs = \sum_{n=1}^{N} \frac{O\ and\ M_N}{(1 + DISCOUNT\ RATE)^N}$$

As earlier mentioned, the Nigerian government has the option of raising the funds for constructing the pipeline from its coffers or from external borrowing. Supposing the finances will be raised 70% through external borrowing with 6% interest, and 30% through equity (regulatory return on equity is 12%).[12] The following equation accounts for the present value of the total yearly payments for debt financing. However, if the Nigerian government decides to provide 100% equity financing, then the equation will not be applicable. For the purpose of this research, we will assume the 70% external financing for the pipeline construction, and the present value of the annual loan amortization is shown in equation 4, which is multiplied by 40 and then discounted to present value. [13]

Equation 4

$$PV\ of\ debt\ financing = \left[\left[\sum_{n=1}^{N} \frac{ICC \times SHARE\ OF\ THE\ DEBT \times INTEREST\ RATE}{1 - \left(\frac{1}{(1 + interest\ rate)}\right)^N}\right] \times 40\right] / (1 + discount\ rate)^{40}$$

Therefore, the model for present value of total life cycle costs for the Nigerian pipeline will be the summation of equation 1, 2, 3, 4. While the model for the present value of the total gas volumes transported over the life cycle of the pipeline is presented below:

Equation 5

$$\text{Gas volume transported} = \sum_{n=1}^{N} \text{Rate of utilization} \times \text{annual pipeline design capacity} \times \text{years of operation}$$

Scenarios for low and high rate of capacity utilization will be shown. For maximum utilization rate, we assume 100% of capacity utilization and 75% for low scenario. So, Levelised transportation cost of the Nigeria natural gas through the proposed gas pipeline will be:

Equation 6

$$\text{LTC} = \frac{\text{Investment costs} + (-\text{PV of tax benefit}) + \text{PV of O and M costs} + \text{PV of debt financing}}{\text{Gas volume transported}}$$

This will give us the cost charges for using the pipeline to transport each trillion cubic meters of natural gas through at the period of forty years (at the present value of the US dollar), so that the investor (Nigerian government) can pay back its total money spent in constructing and maintaining the pipeline system for the period.

III. Data and Assumptions: Levelised Transportation Cost of First Route Alternative (FRA) pipelines

Starting with the first route alternative (FRA), the equation for estimating initial investment costs (IIC) is as follows:

Initial Investment costs (IIC) = E(CCP) + E(CCMS) + other costs.

To estimate the cost of laying down the first alternative route pipelines E(CCP), we will adopt the model established by Shahi Menon (2005). The $E(CCP)$ model recommended by Shahi Menon (2005)[14] suggested that the costs of constructing pipeline include the costs of pipe materials, pipe coating and fittings and the cost of labour for installation. The following model incorporates these parameters in estimating the cost of constructing the gas pipeline.

$$E(CCP) = PMC + PCW + LC$$
$$PCW = PMC \times 5\%$$

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

$$PMC = 0.0246(D - T)TLC$$

Where:
D is the diameter (outside) of the pipe in millimeters (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. For the FRA case, we will have 1364.3km as the total length of the pipeline, diameter of 812.8 mm (81.28cm), wall thickness of 0.5in (12.7mm) and cost of pipe material to be $800 per tonne.[14]

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

$$t = \frac{D_O - D_I}{2}$$
$$t_{FRA} = \frac{32in - 31in}{2} = 0.5in\ (12.7mm)$$

Where, D_O is the diameter outside the pipeline and D_I is the inside diameter of the pipeline. The cost of pipe material ($800 per tonne) is sourced from Shahi Menon (2005), Mohitpour et al (2003) and Tianjin Yuheng Steel Co., Ltd. [15, 16]

$$PMC_{FRA} = 0.0246(812.8mm - 12.7mm) \times 12.7mm \times 1364.3km \times \$800 = \$272{,}824{,}247$$

$$PCW_{FRA} = \$272{,}824{,}247 \times 0.05 = \$13{,}641{,}212$$

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 from. For the purpose of this estimation we adopt the following model. [14]

$$LC_{FRA} = \$15{,}000 \times diameter\ (in) \times length\ (miles)$$

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 kilometer. 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.[15] 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 labourers will be paid base on the international labour cost. Therefore,

$$LC_{FRA} = \$15{,}000 \times 32 \times 847 = \$406{,}560{,}000$$
$$E(CCP)_{FRA} = \$272{,}824{,}247 + \$13{,}641{,}212 + \$406{,}560{,}000 = \$693m$$

The estimated cost of constructing the first route alternative is $693m. Now, to estimate the cost of 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 shown in table 3 above:

Table 3: cost of constructing the first route alternative compressor stations E(CCMS)

Pipeline	Diameter	Capacity Per year	Pressure (bar)	Compressors 5000HP (At each 64 km)	Unit cost ($2000*HP*number of compressors)[14]	Estimated Investment cost (M$)
1. Lagos to OKLNG	81.28 cm	10×10^9 m^3	60	15	($2000*5000HP*15 compressors)	150.00
2.Interconnector	81.28 cm	10×10^9 m^3	60	3	($2000*5000HP*3 compressors)	30.00
3. South-North	81.28 cm	10×10^9 m^3	60	3	($2000*5000HP*3 compressors)	30.00
					TOTAL E(CCMS)	$210.00

Equation 7

$$IIC_{FRA} = \$693{,}025{,}459 + \$210m = \$903m$$

Where, IIC is the estimated initial investment cost. Now, to calculate the tax benefit from assets depreciation over the period of forty years, we use simple **straight line depreciation method** which uses the following formula as: [17],

$$SLD = \frac{IIC}{life\ time}$$

$$SLD_{FRA} = \frac{\$903m}{40} = \$22.6m = 2.5\%\ annually$$

Where SLD_{FRA} is the straight-line depreciation for the First Route Alternative (FRA). The result (2.5%) is the rate at which the value of the assets will depreciate annually. To arrive at the cumulative depreciation figures, the value of IIC is devaluated every year, using 2.5% against the value of each previous year, continuously up to the 40th year. The differences between the

value of each past year and the value of each present year are added to give the cumulative depreciation figures for the economic lifetime of the pipelines, which would have been taxed if not being deducted from the value of the assets. This was manually computed in a spreadsheet, where we arrived at $566.6 million as the total depreciation figure (of the FRA pipelines), and substituted in the following equation (equation 8) assuming 30% corporate tax rate and 10% discount rate. [18]

$$-\sum_{n=1}^{N} \frac{DEPRECIATION_N}{(1 + DISCOUNT\ RATE)^N} \times \text{Tax Rate}$$

Equation 8: Tax benefit

$$PV\ of\ tax\ benefit = -\sum_{n=1}^{40} \frac{\$566.6m_{40}}{(1+0.10)^{40}} \times 0.30 = \frac{\$566.6m}{1.10^{40}} \times 0.30 = \$3.8m$$

$\$3.8m$ is the present value of the cumulative tax benefit (deduction for the economic lifecycle of the pipeline). This represents the amount that pipeline operator would have paid without assets' depreciation. This amount will be deducted from the total initial investment cost.

For the annual operation and maintenance costs of the FRA which includes the maintenance of the compressor stations, we adopt 2% of the value we derived at equation 7 above ($903m), which is $18.1m per annum. That means, for the economic life time of the systems, $724 million nominal future value will be expensed for the operation and maintenance of the pipelines and the compressor stations. This includes the cost of supervision, which is assumed to be done by road. This is expected to be low due to the low labour cost in Nigeria. There is no formal labour cost index in Nigeria, but there is a minimum wage of $120 per month in the public sector (using an average exchange rate of N150 for one US dollar) which is less than US dollar per hour. When compare with the USA and UK average minimum wages of $7.70 and £6.19 per hour respectively, we can expect low labour cost in Nigeria than in USA and UK.[19] [20].However, according to Richardson International Construction Factors Manual [21], the Nigerian weighted average craft rate for a construction worker is $18.45 per day with performance factor of 2.75 better than what is obtained in US.

However, Inflation factor was not considered in estimating the Initial investment cost (IIC), because we assumed that the capital equipment and materials are one off payments, and are to be placed (supplied) in the base year (2013), so there is 0% inflation possibility in the first year. But, in the case of O and M, the effect of inflation can alter the estimation. That is why we will assume the possibility of inflation on the components of the O and M costs, which include 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. We adopt an average annual inflation rate of 5% using general construction index. [22] Since we estimated $724 million to be the nominal cumulative future value of the annual O and M costs for the economic life of the pipe (without inflation), now we will incorporate the inflation factor to derive at the adjusted/real cost figure of O and M. The figure was manually computed in a spread sheet, where the O and M cost in the base year ($18.1m) was used as the base O and M cost, and then we added 5% inflation against each of preceding year up to forty years. The summation of these figures gave us $2.2b as the adjusted cumulative O and M costs for the economic lifetime of the pipelines, which is substituted as O and M figure in the following equation.

$$PV\ of\ O\ and\ M = +\sum_{n=1}^{N} \frac{O\ and\ M_N}{(1 + DISCOUNT\ RATE)^N}$$

Equation 9: O and M costs

$$PV\ of\ O\ and\ M = +\sum_{n=1}^{40} \frac{\$2.2b_{40\ years}}{(1+0.10)^{40\ years}} = \frac{\$2.2b}{(1.1)^{40}} = \$48.3m$$

Therefore, $\$48.3m$ is the present value of the adjusted cumulative O and M cost for the economic life of the pipelines (FRA).
To add the annual loan amortization cost, we substitute our figures in the following equation.

$$\sum_{n=1}^{N} \frac{ICC \times SHARE\ OF\ THE\ DEBT \times INTEREST\ RATE}{1-\left(\frac{1}{(1+interest\ rate)}\right)^{N}}$$

$$\sum_{n=1}^{40} \frac{\$903m \times 0.70 \times 0.06}{1-\left(\frac{1}{(1+0.06)}\right)^{40}} = \frac{\$37.9m}{1-0.097222} = \frac{\$37.9m}{0.902778} = \$40.9m$$

Therefore, $\$40.9m$ is the annual loan amortization cost for the debt of $632m (0.7*$903m), but for the economic life of the pipelines, it will be $40.9m*40= $1.6b. This is what Nigeria or an investor will pay for the principal loan plus the interest within forty years. However, to avoid over accounting the principal loan which is accounted in the initial investment costs, we will deduct the interest from the principal figure which gives us $968 million as the cumulative interest payments (IP) for the economic life time of the pipelines. To adjust this figure to present value, we substitute it in the following equation.

$$\sum_{N=1}^{N} \frac{IP_{40}}{(1+discount\ rate)^{40}}$$

Equation 10: present value of interest payments

$$PV\ of\ interest\ payment = +\sum_{N=1}^{40} \frac{\$968m}{(1+0.10)^{40}} = \frac{\$968m}{(1.1)^{40}} = \$21.4m$$

Therefore, $\$21.4m$ is the present value of the total interest payment for the loan of $632m acquired from external sources. The next model is for the volume of gas to be transported through the FRA pipelines for the forty years. We will assume that the pipeline's capacity will not be utilized maximally, therefore we will assume 70% utilization rate. Equation 11 gives us the volume of natural gas to be transported through the FRA pipelines throughout the economic lifetime of the systems.

$$\sum_{n=1}^{N} Rate\ of\ utilization \times annual\ pipeline\ design\ capacity \times years\ of\ operation$$

Equation 11: volume of gas transported over the economic lifetime of the FRA pipelines

$$Total\ gas\ volume\ transported = \sum_{n=1}^{N} 0.70 \times (30\ 10^9\ m^3) \times 40 = 840\ 10^9\ m^3$$

Therefore, the total amount of natural gas to be transported at 70% utilization rate for forty years is eight hundred and forty billion cubic metres of natural gas ($840\ 10^9\ m^3$). At 85% utilization rate, it will be $1020\ 10^9\ m^3$ and at 100%, it will be $1200\ 10^9\ m^3$.
Thus, to arrive at the final LTC (levelised transportation cost) for the FRA pipelines we will then add equations 7, 8, 9 and 10, and then divide the result by equation 11. This is as follows:

$$LTC_{FRA} = \sum_{n=1}^{40} \frac{\$903m + (-\$3.8m) + \$48.3m + \$21.4m}{840\ 10^9\ m^3}$$

$$LTC_{FRA} = \sum_{n=1}^{40} \frac{\$968{,}900{,}000}{840\ 10^9\ m^3} = \$1.2m/10^9\,m^3$$

IV. Results, Discussion and conclusion

The SRA calculations is not presented due to the paper size limit. However, looking at the summary of results from the two options (table 5), government and investors can have a clear understanding of the life cycle cost of the each of the gas pipelines. It will cost $1.2 million to transport one billion cubic meters (bcm) of natural gas on the FRA, and for the economic lifetime of the pipeline, 840 bcm will be transported. For the SRA pipeline, $1.5 million will be spent to transport one bcm with 1400 bcm as total volume of gas to be transported within 40 years. The volume of gas transported and LTC of the SRA pipeline are higher than that of the FRA. SRA pipeline represents 67 percent increase on the FRA pipeline capacity (Volume of gas transported), and 152 percent increase in kilometer distance.

COST ITEM	*FIRST ROUTE ALTERNATIVE*	*SECOND ROUTE ALTERNATIVE*
Initial investment cost	*$903m*	$\$1.950b$
PV of Tax Benefit	*$3.8m*	$\$8m$
PV of Operation and maintenance cost	*$48.3m*	$\$104m$
Annual Amortization cost	*$40.9m*	$\$90.7m$
PV of interest payment	*$21.40m*	$\$48.6m$
Kilometre coverage	*1,164.32*	2,934.37
Volume of gas transported	$840\ 10^9\ m^3$	$1400\ 10^9\ m^3$
Levelised transportation cost	$\$1.2m/10^9m^3$	$\$1.5m/10^9m^3$

Table 4: Comparison between FRA and SRA

The length of the second route alternative option is 2.5 times higher than the first alternative route, and the capex of the SRA is 115% higher than the FRA, yet there was relatively modest increase in LTC (+25%). That is to say, 152% increase in distance, 115% increase in capex and 67% increase in capacity will lead to 25% increase in LTC.

Similarly, to observe the effect of capacity increase on the LTC, the pipeline capacity of the SRA was deliberately manipulated (increased) many times in order to observe changes in the LTC while keeping the coverage (distance) constant; the LTC was discovered to continue to fall as capacity increases. The result is shown in figure 3 below.

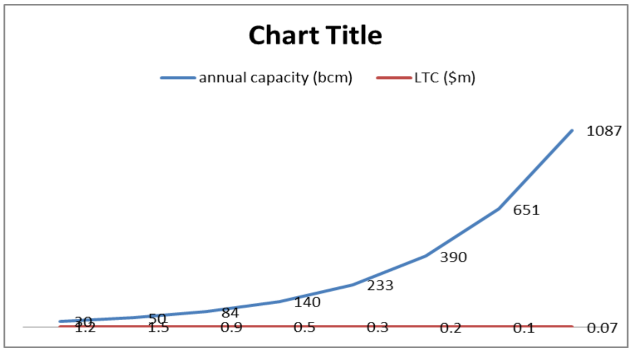

Figure 3: Annual Capacity vs LTC

Therefore, we can conclude that it is more economical to have large gas pipeline capacity as more capacity leads to low Levelised Transportation Cost. This justifies the need to operate gas pipelines at their full capacities, as low capacity use leads to higher LTC. It also implies that big increase in the gas pipeline capacity will results to relatively low increase in LTC. It is recommendable if Nigerian government will consider the second alternative route as it covers almost every part of the country, covering most of the demand areas (109 million population supply reach), hence more potential to meet large energy demands compare to the first option (54 million population supply reach). Investing in the SRA will also serve long-term investment need, as all potential demand areas are covered.

LTC is an indicator of economic viability of a pipeline, and the finding of this paper will guide investors and government on the lifecycle costs of constructing and running a gas pipeline in Nigeria. If investors know how much each volume of gas will cost to transport along a pipeline system in Nigeria, it will help in attracting more investment opportunities in the country's gas sector. Once gas pipelines are constructed covering most of the demand areas, it is recommended that other gas development projects like Gas to Power Plants and Gas to Liquids Plants be built to supply electricity and gasoline to the commercial and residential sectors, which will enhance energy accessibility and boost the economy. Therefore, it is important to analyze the profitability of these two gas development projects in the country, and to study the effect of inland gas consumption on the overall economic performance of the country's economy.

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It is more economical to have large gas pipeline capacity, as more capacity leads to low Levelised Transportation Cost.