IJETMR
International Journal of Engineering Technologies and Management Research
A Knowledge Repository

ECONOMIC FRAMEWORK FOR GAS PIPELINE DEVELOPMENT IN NIGERIA

Henry Biose [1], Professor Adewale Dosunmu [2], Dr. Chijioke Nwaozuzu [3]
[1, 3] Emerald Energy Institute for Petroleum and Energy Economics, Policy and Strategic Studies, University of Port Harcourt, Nigeria
[2] Department of Petroleum and Natural Gas Engineering, University of Port Harcourt, Nigeria

Abstract:
The paper present an economic model and framework for the development of natural gas pipeline for sustainable economic development in Nigeria. The study reviewed the economics of natural gas pipeline development in Nigeria. The research formulated an economic model for a case study of Calabar to Ajaokuta 417km gas pipeline project and a discounted cash flow for an economic life of 40 years. The project economics indicates a Net Present Value (NPV) of 12.5 billion USD with a discounted payback period of 7 years and 9 nine months, Profitability Index (PI) of 7.30, Internal Rate of Return of 23.05% and Growth Rate of Return 26.97% and these project economic indicator shows that the gas pipeline investment is viable. This study provides an economic model that would guarantee security of gas supply, provide access to clean energy and provides an economic framework to support long term natural gas pipeline development in Nigeria.

Keywords: Natural Gaspipeline; Economic Model; Economic Framework; Sustainable Economic Development.

Cite This Article: Henry Biose, Professor Adewale Dosunmu, and Dr. Chijioke Nwaozuzu. (2019). "ECONOMIC FRAMEWORK FOR GAS PIPELINE DEVELOPMENT IN NIGERIA." *International Journal of Engineering Technologies and Management Research*, 6(12), 46-63. DOI: https://doi.org/10.29121/ijetmr.v6.i12.2019.474.

1. Introduction

There is no economic model for the long term development of natural gas transmission gas pipeline for socio-economic development in Nigeria and this has resulted to having few natural gas pipelines spread across the various regions or geopolitical zones (DPR, 2017). There is currently about 1,500 to 2,000km of natural gas pipelines spread across Nigeria with the majority of pipeline within the eastern and western Nigeria (NGC, 2017). The inadequacy of these natural gas pipeline has resulted to poor domestic gas supply obligation to support economic activities in Nigeria (DPR, 2017).

Odunuga (2016) stated that about 400 trillion cubic feet (tcf) to600 trillion cubic feet(tcf) of natural gas in Nigeria is still to be discovered, which is about 7.7 percent to 11.5 percent of the total global quantity of natural gas that is yet to be discovered and this is a huge economic gain with respect to

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

economic development in Nigeria through gas based industrialization; however, the gap therein is the lack of gas resource management plan for structured economic development.

According to Baru (2018), gas flaring in Nigeria is at 800 mmscfd (a reduction from 25 percent to about 10 percent) and with a projection to be at zero gas flaring by the year 2020 with gas commercialization projects worth about $25billion investment to be spread over a ten (10) year period. But,there is insignificant contribution of the natural gas sector to economic development in Nigeria due to insufficient pipeline infrastructures for effective gas transmission and distribution.

When natural gas is produced from the reservoirs and wellheads, they are transported through pipelines to a gas hub or centre for processing or further usage. The gas buyer popularly known as off takers are usually connected with processing facility to buy these raw dry or wet gas ; Gas distribution is done also through onshore pipelines in other various processed forms such as cooking gas cylinders, compressed natural gas trucks (Hilyard, 2012).

Nwaozuzu (2018) also explained that the cost for transportation of natural gas is a critical element that determines the natural gas economics and it is driven by economics of scale that shows the more the volumes, the cheaper the unit cost of supply.

Carol and Hudskin (2010) posit that the main cost associated with gas pipeline development are the cost of capital and the operating cost of the pipeline system, it indicates that a pipeline that is well designed, would experience an optimized annual cost of compression and fixed cost of the pipeline. The total cost of the pipeline development also includes the fixed charges as shown in equation 1.0 and figure 1.0 respectively.

Total Cost=Capital Cost+Operating Cost+Fixed Charges 1.0

The capital cost comprise mainly of the initial cost of the pipeline material and the compressor station, therefore the optimum size of pipeline is relevant in achieving an effective and economic gas pipeline system, this study also assumes that the pipeline and compressor are in operation for 350 days in a year and that translate to 0.95 utilization factor or 95% efficiency (Carol and Hudskin, 2011).

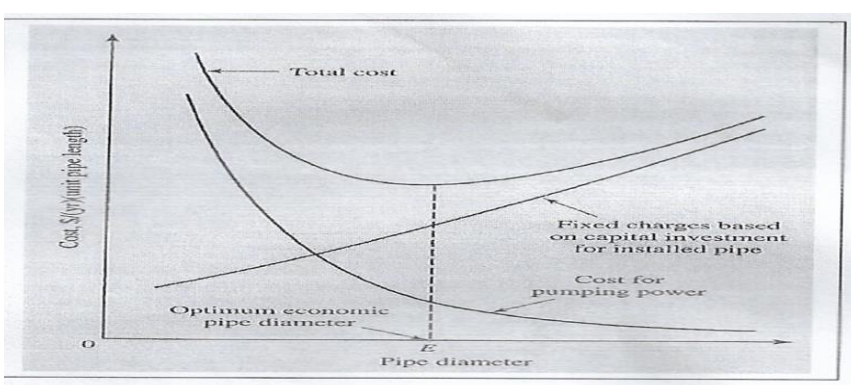

Figure 1.0: Total cost of pipeline installation viz-a-viz pipe diameter.
Source: Carol and Hudkins (2010)

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

The purpose of this study is to present an economic model and framework for the development of natural gas pipeline for sustainable economic development in Nigeria.

This study is significant, because it will support the optimal utilization of domestic gas in the form of Liquefied Natural Gas (LPG) in Nigeria and would support economic development (Oluwabunmi, 2014).

The scope of this research covers the proposed onshore gas pipeline from Calabar to Enugu to Ajaokuta (417km) as shown in figure 1.1. This proposed Calabar to Ajaokuta Pipeline (CAP) project is a critical infrastructure that would spread and increase the gas pipeline transmission and distribution networks in Nigeria and it is a necessary project that will support the optimization of the domestic gas supply obligation

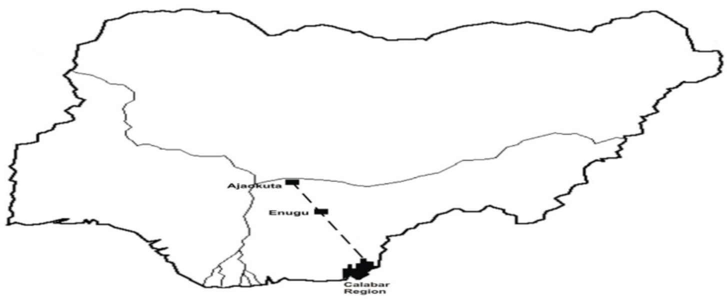

Figure 1.1: Calabar to Ajaokuta Gas Pipeline Route Map

The aim of this paper is to present an economic framework and model required for the development of natural gas pipelines in Nigeria.

2. Materials and Methods

The study adopts an economic analysis, analytical framework and spreadsheet model to determine relationship between key variables and the model developed would be used to determine the long run relationship for a typical gas pipeline infrastructure in Nigeria.

The case study pipeline is the Nigerian National Petroleum Corporation proposed CAP gas pipeline (Calabar to Ajaokuta), as this pipeline has been identified as a critical gas infrastructure in Nigeria.

The key steps in this research are as follows:
1) Definition of the problem / Gas pipeline route
2) Specification of the gas delivery volume / Pipe Material Cost
3) Estimation of cost of capital considering weighted average
4) Estimation of annual operating and maintenance cost
5) Estimation of depreciation and salvage value
6) Computation of Net Present Value (NPV)
7) Computation of Internal Rate of Return
8) Computation of pay back period method
9) Sensitivity analysis

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

The formulae for calculation required for the total cost build up for the economic analysis and modeling are shown in the appendix.

A dynamic deterministic model is developed using the various relevant equations, in a microsoft excel spreadsheet. The key economic indicators in this deterministic analysis includes; the Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI) and Growth Rate of Return (GRR) and payback period.

According to Mian (2011), Net Present Value (NPV) is also referred to as the present value of the cash surplus or present worth and can be obtained from the weighted average cost of capital of the investor and the Net Present Value (NPV) is given by equation 2.1.

$$NPV = \frac{FV}{(1+r)^n} \quad 2.1$$

Where:

FV = future value,
r = discount rate
n = is the period

According to Mian (2011), the Internal Rate Return (IRR) is the discount rate at which the Net Present Value (NPV) equals zero or the present value of cash inflows is equal to the present value of cash outflows. The equation 2.2 shows the Internal Rate of Return (IRR) as follows:

$$\sum_{t=1}^{n} \frac{NCF_t}{(1+IRR)^t} = 0 \quad 2.2$$

Where:

NCF = Net Cash Flow
IRR = Internal Rate of Return
t = the net cash flow at time, t

Mian (2011), states that profitability index is dimensionless ratio that shows the present value benefit that is obtained from an investment. It can also be termed as investment efficiency, discounted profit –to-investment ratio (DPIR), present value index (PVI) or present value ratio (PVR).

$$PI = 1 + \frac{NPV}{PV\ of\ Capital\ Investment} \quad 2.3$$

Where:
PI = Profitability Index
NPV = Net Present Value
PV = Present value

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

Mian (2011) states that the growth rate of return is used to establish a more reliable measure of profitability that is superior to the profitability index and internal rate of return. The growth rate of return for continuous compounding is given by equation 2.4

$$GRR = \frac{1}{t}\, In\,(PI) + i_d \qquad 2.4$$

Where:

GRR: Growth rate of return
i_d: reinvestment rate, fraction
PI: Profitability index
t: time or period (years)

According to Ahmed (2017), the discounted payback period shall be determined with equation 2.5

$$Discounted\ Payback\ Period = A + \frac{B}{C} \qquad 2.5$$

Where:

A = Is the period where last negative discounted cash flow was recorded
B = Is the absolute value of the last negative cumulative discounted cash flow at period A
C = Is the discounted cash flow value after period A

To establish the probabilistic nature of the dependant and independent variables, sensitivity analysis using the Pallaside @ Risk software is used to establish stochastic nature of the variables (dependent and independent variable) using the Monte Carlo technique. Seba (2008), states that the Monte Carlo simulation is a technique of dealing with uncertainty that requires a mathematical model of the situation as the study recognizes all the important factors. According to http://www.scratchapixel.com(2019), Monte Carlo approximation is expressed mathematically as shown in equation 2.6.

$$E(X) \approx \frac{1}{N}\sum_{n=1}^{N} x_n. \qquad 2.6$$

Where the mathematical sign ≈ shows that the formula on the right side of this indicates an "approximation" of what the random variable X expectation E(X) actually is.

N = Number of samples

Xns = average of random values

The model assumption and input data for this economic analysis is shown in Appendix B and Appendix C respectively.

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

The major sources of data in this study include the following:
1) Department of Petroleum Resource Annual Reports
2) Central Bank of Nigeria
3) Nigerian National Gas Policy (2017)

3. Results and Discussions

3.1. Economic Analysis of Calabar to Ajaokuta 417km Natural Gas Pipeline

The economic analysis is carried out basically in two perspectives and these are the deterministic economic analysis and probabilistic economic analysis. The gas pipeline material that is considered in this study is carbon steel in accordance with the international standard or specification (such as API 5L and ASME B31.8) for gas pipelines. The deterministic analysis uses equations 2.1 to equation 2.5 and the formulae in Appendix A to obtain the endogenous or dependent variable, which includes the Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Growth Rate of Return (GRR) and Payback Period. These parameters are considered in this study as profitability and economic indicator for the Calabar to Ajaokuta 417km gas pipeline. The exogenous or independent variable in the economic modeling and analysis of this gas pipeline includes; the annual net revenue revenue, tax payable etc. The pipeline system description is shown in table 3.1 and this shows a total gas volume of 1950mmscfd (Calabar to Enugu with 700mmscfd and Enugu to Ajaokuta with 1250mmscfd). The specified gas pipeline diameters is 48inches for Calabar to Enugu and from Enugu to Ajaokuta has a diameter of 36inches. The total pipeline length is 417km (179km from Calabar to Enugu and 238km from Enugu to Ajaokuta).

Table 3.1: Pipeline system description

S/N	**Pipe Size (Inches)**	**Gas Quantity (mmscfd)**	**Source**	**Destination**	**Remark**	**Length (km)**
1	36	1250	Enugu	Ajaokuta	Proposed critical gas pipeline	238
2	48	700	Calabar	Enugu	Proposed critical gas pipeline	179
Total Volume of Gas (mmscfd)		1950	Total Pipeline Length (Km)			417

Source: National Gas Policy (2017)

Pipeline materials cost is calculated using equation 6.4 and the parameters are coded into the excel spreadsheet or worksheet. The basic assumption for pipeline materials cost is based on $800 per metric tonne of carbon steel and this is as per historical gas pipeline project cost (Ahmed, 2017).The calculated cost of the carbon steel pipeline materials (12.7mm thickness) is One hundred seven million six hundred fourteen thousand four hundred sixty-eight dollars sixty-four cents ($107,614,468.64) as shown in table 3.2.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

Table 3.2: Pipeline material cost

Pipeline Material Cost						
S/N	**Pipeline Route**	**Diameter (mm)**	**Length (Km)**	**Pipeline Thickness (mm)**	**Pipe Material Cost ($/Metric ton)**	**PMC ($)**
1	Enugu - Ajaokuta	914.4	238	12.7	800	5.36E+07
2	Calabar - Enugu	1219.2	179	12.7	800	5.40E+07
Total cost of the pipeline material ($ Million)						108

The labour cost is calculated using equation 6.5, the unit factor for the average labour cost is $40,750 per diameter per miles for 36 inches pipeline and $45,000 per diameter per mile during the installation and this is in accordance with Carol and Hudskin (2015). In the historical pipeline construction cost analysis by Rui et al (2011), it posits that the labour construction cost has an annual growth rate of 0.90%. According to National Bureau of Statistics (2018), Nigeria has been experiencing high unemployment rate with respect to the working age of 15 to 64 years between the year 2017 to 2019; the unemployment rate increased from 18.8% in third quarter of year 2017 to 23.1% in the third quarter of year 2018, the unemployment rate for 2019 is 23.1% and with a projection to hit 33.5% by 2020. As a result of this high unemployment rate, the labour cost in considered in this study not to be affected by the annual growth of 0.90%.The pipeline diameters and lengths are coded into the excel worksheet and the total labor cost of four hundred fifty-seven million one hundred ninety-six thousand sixty-six dollars and zero cents ($457,196.066.00) as shown in table 3.3.

Table 3.3: Cost of labour for construction and installation of the pipelines

Cost of labour for Construction / Installation of the Pipeline					
S/N	**Pipeline Route**	**Diameter (Inches)**	**Length (Miles)**	**Average Unit Labour Cost ($)**	**Labour Cost (Sub Total) ($)**
1	Enugu - Ajaokuta	36	147.8863	40,750	216,949,202.00
2	Calabar - Enugu	48	111.2254	45,000	240,246,864.00
Total cost of labour ($)					457,196,066.00

The compressor station is built at every 64km based on historical gas pipeline design premise or information. The number of compressors station required from Calabar to Enugu is three (3) over a distance of 179km and from Enugu to Ajaokuta is four (4) compressor stations over a distance of 238km. The total cost for installing the compressor stations is obtained using an excel worksheet with horse power required and other parameters coded in equation 6.4 and thereafter a total cost of seven million dollars and zero cents ($70,000,000.00) is obtained as shown in table 3.4.

Table 3.4: Cost of construction and installation of compressor

Cost of Constructing Compressor Stations						
S/N	**Pipeline Route**	**Diameter (Inches)**	**Length (km)**	**Compressor (@ 64km each)**	**Horsepower**	**Cost of Compressor ($2000*HP*number of compressors)**
1	Enugu - Ajaokuta	914.4	238	4	5000	40.0E+6

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

2	Calabar - Enugu	1219.2	179	3	5000	30.0E+6
Total cost of constructing compressor stations ($ Million)						70

The gas capacity for the pipelines is 255,550 mmscf per year for the 48 inches, 179km pipeline and 456,250 mmscf per year for 36 inches, 238km pipeline as detailed in table 3.5.

Table 3.5: Gas pipeline capacity

Gas Capacity for the Pipelines						
S/N	**Pipeline Route**	**Diameter (Inches)**	**Length (Km)**	**Capacity (mcm/year)**	**Capacity (mmscf/year)**	**Capacity (bcm/year)**
1	Enugu - Ajaokuta	914.4	238	12,920	456,250	12.92
2	Calabar - Enugu	1219.2	179	7,235	255,500	7.23
Gas Capacity for the Pipelines (mcm/year, mmscf/year and bcm/year)				20,155	711,750	20.15

Source: National Gas Policy (2017)

The Weighted Average Cost of Capital (WACC) is the average after-tax cost of various capital sources (equity and long-term debt) required to finance the Calabar to Ajaokuta 417km of gas pipeline; The Weighted Average Cost of Capital indicates the average rate the investor expects to pay to finance its assets. WACC is computed using equation 6.9a in order to determine and obtain the discount rate (using equation 6.10) that is necessary for the project investment cash flow analysis. The obtained Weighted Average Cost of Capital is calculated using an excel workshop and this is shown in table 3.6; the calculated Weighted Average Cost of Capital (WACC) for the various phases is as obtained are as follows:

- 2019 to 2021 (3 years period) with WACC of 5%
- 2022 to 2023 (2 years period) with WACC of 18 %
- 2024 to 2033 (10 years period) with WACC of 17 %
- 2034 to 2043 (10 years period) with WACC of 19 %
- 2044 to 2053 (10 years period) with WACC of 22 %
- 2054 to 2058 (5 years period) with WACC of 22 %

Table 3.6: Weighted Average Cost of Capital

Project Phase (Period/Year)	2019-2021 (3yr)	2022-2023 (2yr)	2024-2033 (10 yr)	2034-2043 (10 yr)	2044-2053 (10 yr)	2054-2058 (5 yr)
Cost of Equity (K_e)	$K_e = r_f + \beta(r_m - r_f)$	$K_e = r_f + \beta(r_m - r_f)$	$K_e = r_f + \beta(r_m - r_f)$	$K_e = r_f + \beta(r_m - r_f)$	$K_e = r_f + \beta(r_m - r_f)$	$K_e = r_f + \beta(r_m - r_f)$
Unweighted Cost of Equity	0.1565	0.1935	0.224	0.26	0.293	0.323
Cost of Debt (K_d)	$K_d = r * (1 - TR)$	$K_d = r * (1 - TR)$	$K_d = r * (1 - TR)$	$K_d = r * (1 - TR)$	$K_d = r * (1 - TR)$	$K_d = r * (1 - TR)$
Unweighted Cost of Debt	0	0.180	0.14	0.154	0.175	0.162
Weighted Cost of Capital	$(35\%K_e) + (65\%K_d)$	$(35\%K_e) + (65\%K_d)$	$(35\%K_e) + (65\%K_d)$	$(35\%K_e) + (65\%K_d)$	$(35\%K_e) + (65\%K_d)$	$(35\%K_e) + (65\%K_d)$
Weighted Cost of Capital (WACC)	**0.05**	**0.18**	**0.17**	**0.19**	**0.22**	**0.22**

The pipeline system economic analysis is for an economic life of fourty years (40yrs) and the summary and details is shown in table 3.7. The variables are coded in an excel workshop to obtain each values at each of the project. The utilization factor or availability of the pipeline is considered to be 80% in this study.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

The pipeline system shall be available for 292 days in a year in accordance with equation 3.1

Pipeline Availability =Utilization factor x 365 days 3.1

The Calabar to Ajaokuta gas pipeline development investment is modeled for financing arrangement of 35% equity ($691,974,146.58) and debt of 65% ($1,285,094,843.65). The assets (capital expenditure of $1,977,068,990.23) is depreciated using straight line depreciation method (as per equation 6.6b) and the salvage value is obtained using equation 3.2

$$Dr = \left(\frac{IIC}{Economic\ Life}/IIC\right)\ X\ 100 \qquad 3.2$$

Where:
Dr=Depreciation rate
IIC = Initial Investment Cost

The depreciation is important in this study, because the corporate income tax rate is calculated against the depreciated value of the assets. There is a tax holiday for the first three (3) years and then the next two (2) years; this is in accordance with the fiscal incentive for midstream and downstream gas project development in Nigeria; The tax rate of 30% is applied in the subsequent phases of the project in accordance with corporate income tax policy in Nigeria. The gas pipeline economic analysis is based on a three years free interest rate period (moratorium) in order to accommodate the detailed engineering, procurement and construction phase of the project. The interest rate applies on the second phase of the project and throughout the economic life as in table 3.7. The transportation cost of $0.85 / mcf is applied in the second phase (2022 – 2023) and further transportation cost considered in the study is as follows:

- 2024 to 2033 (10 years period) with transportation cost of $0.90 / mcf
- 2034 to 2043 (10 years period) with transportation cost of $0.95 / mcf
- 2044 to 2053 (10 years period) with transportation cost of $1.0 / mcf
- 2054 to 2058 (5 years period) with transportation cost of $1.0 / mcf

The total project investment cost is based on equation 3.3;

Total Project Cost=Capital Cost + Operating Cost 3.3

Operating cost associated cost after the commissioning of the gas pipeline system and these includes: maintenance cost, cost of wages/salaries and miscellaneous cost. The operating cost is calculated as follows:

Operating Cost =Percentage x Capital Cost 3.4

The percentages considered in this study for the various phases of the project investment is as follows:

- 2019 to 2021 (3 years period) with operation and maintenance rate of 0%
- 2022 to 2023 (2 years period) with operation and maintenance rate of 2%

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

- 2024 to 2033 (10 years period) with operation and maintenance rate of 3%
- 2034 to 2043 (10 years period) with operation and maintenance rate of 4%
- 2044 to 2053 (10 years period) with operation and maintenance rate of 4.5%
- 2054 to 2058 (5 years period) with operation and maintenance rate of 5 %

The initial phase (2019 to 2021) has an operation and maintenance rate of 0%, because there was no operation as the project is in detailed engineering, procurement and construction/installation phase. The operation and maintenance rate of 2% applies in the second phase (2022 to 2023), because the gas pipeline is in operation. The operation and maintenance rate is increased by 1% in the first three phases and in the last phase by 0.5% due to ageing of the pipeline system over the economic life of 40 years.

The annual revenue in each phase of the gas pipeline economic model as shown in table 3.7 is given by equation 3.5:

$$Annual\ Revenue = Actual\ Gas\ Delivery(mcf)\ X\ \ Transp\ Cost\ (\$/mcf) \qquad 3.5$$

The obtained values for the annual cash flow in each phase of the gas pipeline as shown in table 3.7 is coded into the excel model using equation 3.5

$$Annual\ Cash\ Flow\ = Net\ Revenue - \ Tax\ Payable \qquad 3.6$$

3.2. Discounted Cash Flow Analysis of The Gas Pipeline Project

The discounted cash analysis is obtained based on the discount rate (WACC+1%) and annual cash flow throughout the economic life (40 years) of the project and this is coded in an excel worksheet. Table 3.2.1 shows the details of the discounted cash flow model with a Net Present Value (NPV) of Twelve billion four hundred fifty-nine million four hundred ninety-nine thousand three hundred twenty-two dollars forty-five cents ($12, 459,499,322.45). The annual operating net cash flow is three hundred nineteen million five hundred twenty-five thousand four hundred eighty-six dollars thirty-nine cents ($319,525,486.39) obtained by using equation 3.2.1

$$Operating\ Net\ Cash\ Flow\ = \frac{Net\ Present\ Value}{Economic\ life} \qquad 3.2$$

3.2.1. Profitability Analysis of The Gas Pipeline Project

The study and project profitability analysis is based on the Internal Rate of Return (IRR), Discounted pay back period, Profitability Index (PI), and Growth Rate of Return (GRR). The output or values of the profitability indicators are shown in table 3.2.1 with an internal rate of return of 23.05%, profitability index of 7.30, the growth rate of return of 26.97% at an average 22% reinvestment rate (reinvestment rate obtained using equation 3.2.1 and a payback period of seven years and nine months.

$$Annual\ Reinvestment\ Rate = \frac{Net\ Annual\ Revenue}{Capital\ Expenditure} \qquad 3.2.1$$

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

Table 3.7: Economic Analysis for Calabar

Economic Analysis (Calabar - Enugu-Ajaokuta, 417km Pipeline System)

S/N	Item Description	EPC Phase (2019-2021) (3yrs)	Operation & Maintenance (2022-2023) (2yrs)	Operation & Maintenance (2024-2033) (10 yrs)	Operation & Maintenance (2034-2043) (10 yrs)	Operation & Maintenance (2044-2053) (10 yrs)	Operation & Maintenance (2054-2058) (5 yrs)
1	Capital Cost ($) - Working	1,977,068,990.23	1,977,068,990.23	494,267,247.56	695,919,640.84	710,472,594.75	715,808,285.14
2	Equity ($)	691,974,146.58	691,974,146.58	172,993,536.64	243,571,874.29	248,665,408.16	250,532,899.80
3	Debt ($)	1,285,094,843.65	1,285,094,843.65	321,273,710.91	452,347,766.55	461,807,186.59	465,275,385.34
4	Interest Rate (Prime Lending Rate)	0%	18%	20%	22%	25%	27%
5	Cost of debt (K_d)	0.00%	18.00%	14.00%	15.40%	17.50%	16.20%
6	Beta (β)	0.9	0.85	0.80	0.75	0.70	0.65
7	Free Risk Rate	8.00%	10.00%	12.00%	14.00%	16.00%	18.00%
8	Equity Risk Premium	8.50%	11.00%	13.00%	16.00%	19.00%	22.00%
9	Market Portfolio Return	16.50%	21.00%	25.00%	30.00%	35.00%	40.00%
10	Cost of Equity (CAPM)	15.65%	19.35%	22.40%	26.00%	29.30%	32.30%
11	WACC (Discount rate)	5.48%	18.47%	16.94%	19.11%	21.63%	21.84%
12	Amortization Cost ($)	-	44,368,114.56	82,844,422.96	88,530,872.19	97,275,623.19	67,240,989.00
13	Depreciation Rate	0.00%	50.00%	8.33%	4.55%	3.13%	2.70%
14	Salvage Value ($)	1,977,068,990.23	494,267,247.56	695,919,640.84	710,472,594.75	715,808,285.14	717,382,143.37
15	Depreciation Value ($)	0.00	1,482,801,742.67	-201,652,393.29	-14,552,953.91	-5,335,690.38	-1,573,858.23
16	Annual Depreciation Value ($)	0.00	148,280,174.27	-20,165,239.33	-1,455,295.39	-533,569.04	-157,385.82
17	Tax Rate	0%	0%	30%	30%	30%	40%
18	Annual Operation & Maintenance Cost ($)	-	39,541,379.80	14,828,017.43	27,836,785.63	31,971,266.76	35,790,414.26
19	Annual Gas Delivery (bcm)	-	20.15	20.15	20.15	20.15	20.15
20	Annual Gas Delivery (mcf)	-	711,749,803.15	711,749,803.15	711,749,803.15	711,749,803.15	711,749,803.15
21	Availability factor (days of operations/yr)	-	80%	80%	80%	80%	80%
22	Actual Gas Delivery (mcf)	-	569,399,842.52	569,399,842.52	569,399,842.52	569,399,842.52	569,399,842.52
23	Transp Cost of Natural Gas $/Mcf	-	0.85	0.90	0.95	1.00	1.00
24	Annual Revenue ($)	0.00	483,989,866.14	512,459,858.27	540,929,850.40	569,399,842.52	569,399,842.52
25	Net Annual Revenue ($)	0.00	444,448,486.34	497,631,840.84	513,093,064.76	537,428,575.76	533,609,428.26
26	Gross Tax Payment ($)	0.00	0.00	149,289,552.25	153,927,919.43	161,228,572.73	213,443,771.31
27	Tax Benefit from Depreciation ($)	0.00	0.00	32,028,733.73	17,271,769.03	11,824,319.11	13,618,236.18
28	Tax Payable ($)	0.00	0.00	117,260,818.52	136,656,150.40	149,404,253.62	199,825,535.12
29	Annual Cash Flow ($)	0.00	444,448,486.34	380,371,022.32	376,436,914.36	388,024,322.14	333,783,893.14
30	Tax on selling at Salvage Value ($)	-	0.00	208,775,892.25	213,141,778.43	214,742,485.54	286,952,857.35
31	Net Gain ($) on salvage value	-	494,267,247.56	487,143,748.59	497,330,816.33	501,065,799.60	430,429,286.02
32	Annual Reinvestment Rate (%)	-	0.22	1.01	0.74	0.76	0.75

3.3. Sensitivity Analysis

Stochastic modeling is done in this study using @risk pallaside software to determine the uncertainties associated with the long-term development of Calabar to Ajaokuta gas pipeline. The pipeline economic analysis model (table 3.7) and discounted cash flow model (3.2.1) is subjected to 100 iterations. Appendix D shows the Probability Density Function (PDF) of the net present value (NPV) indicating a mean NPV of $12,470,000,000 minimum obtainable NPV is $4,320,000,000 and maximum obtainable NPV is $20,410,000,000. The standard deviation of the NPV is $3,663,000,000.00.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

Table 3.2.1: Discounted cash flow model for the gas pipeline

Year	Period	Cash Flow ($)	Discount rate (%)	Discount Factor	Discounted Cash Flow (NPV) ($)	Cumulative DiscountedCash Flow ($)
	0	-1.98E+09	0.00	1.0000	-1.98E+09	-1.98E+09
2019	1	0.00E+00	0.06	0.9392	0.00E+00	-1.98E+09
2020	2	0.00E+00	0.06	0.8820	0.00E+00	-1.98E+09
2021	3	0.00E+00	0.06	0.8284	0.00E+00	-1.98E+09
2022	4	4.44E+08	0.19	0.4908	4.44E+08	-1.53E+09
2023	5	4.44E+08	0.19	0.4108	4.44E+08	-1.09E+09
2024	6	3.80E+08	0.18	0.3716	3.80E+08	-7.08E+08
2025	7	3.80E+08	0.18	0.3150	3.80E+08	-3.27E+08
2026	8	3.80E+08	0.18	0.2671	3.80E+08	5.29E+07
2027	9	3.80E+08	0.18	0.2265	3.80E+08	4.33E+08
2028	10	3.80E+08	0.18	0.1920	3.80E+08	8.14E+08
2029	11	3.80E+08	0.18	0.1628	3.80E+08	1.19E+09
2030	12	3.80E+08	0.18	0.1381	3.80E+08	1.57E+09
2031	13	3.80E+08	0.18	0.1171	3.80E+08	1.95E+09
2032	14	3.80E+08	0.18	0.0993	3.80E+08	2.34E+09
2033	15	3.80E+08	0.18	0.0842	3.80E+08	2.72E+09
2034	16	3.76E+08	0.20	0.0533	3.76E+08	3.09E+09
2035	17	3.76E+08	0.20	0.0444	3.76E+08	3.47E+09
2036	18	3.76E+08	0.20	0.0369	3.76E+08	3.84E+09
2037	19	3.76E+08	0.20	0.0308	3.76E+08	4.22E+09
2038	20	3.76E+08	0.20	0.0256	3.76E+08	4.60E+09
2039	21	3.76E+08	0.20	0.0213	3.76E+08	4.97E+09
2040	22	3.76E+08	0.20	0.0178	3.76E+08	5.35E+09
2041	23	3.76E+08	0.20	0.0148	3.76E+08	5.73E+09
2042	24	3.76E+08	0.20	0.0123	3.76E+08	6.10E+09
2043	25	3.76E+08	0.20	0.0102	3.76E+08	6.48E+09
2044	26	3.88E+08	0.23	0.0050	3.88E+08	6.87E+09
2045	27	3.88E+08	0.23	0.0041	3.88E+08	7.26E+09
2046	28	3.88E+08	0.23	0.0033	3.88E+08	7.64E+09
2047	29	3.88E+08	0.23	0.0027	3.88E+08	8.03E+09
2048	30	3.88E+08	0.23	0.0022	3.88E+08	8.42E+09
2049	31	3.88E+08	0.23	0.0018	3.88E+08	8.81E+09
2050	32	3.88E+08	0.23	0.0015	3.88E+08	9.20E+09
2051	33	3.88E+08	0.23	0.0012	3.88E+08	9.58E+09
2052	34	3.88E+08	0.23	0.0010	3.88E+08	9.97E+09
2053	35	3.88E+08	0.23	0.0008	3.88E+08	1.04E+10
2054	36	3.34E+08	0.23	0.0006	3.34E+08	1.07E+10
2055	37	3.34E+08	0.23	0.0005	3.34E+08	1.10E+10
2056	38	3.34E+08	0.23	0.0004	3.34E+08	1.14E+10
2057	39	3.34E+08	0.23	0.0003	3.34E+08	1.17E+10
2058	40	7.64E+08	0.23	0.0003	7.64E+08	1.25E+10
			Net Present Value ($)		**12,459,499,322.45**	
Internal Rate of Return (IRR)			**23.05%**			
Profitability Index (PI)			**7.30**			
Growth Rate of Return @ 22%			**26.97%**			
Discounted Pay Back Period (Yrs)			**7.86**			

4. Conclusion and Recommendation

The economic analysis in this research paper provides an approach to model natural gas pipeline infrastructures for policy analysis in Nigeria and investors can use this approach to determine the short term, medium term and long term profitability of their investment. The analysis estimated the discount rate, annual operating and maintenance cost, annual revenue, tax revenue to the government, annual cash flow et cetra. The discount rate and annual cash flow is used to obtain the discounted cash flow analysis for the gas pipeline project. The Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Growth Rate of Return (GRR) and discounted payback period is obtained from the cash flow analysis respectively. The outcome of the deterministic economic analysis shows that the gas pipeline project is profitable throughout the economic life of forty (40) years. The stochastic or probabilistic analysis shows that the capital cost and operation / maintenance cost is highly correlated with the Net Present Value.

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

This research helps correct the limitation in long term economic planning for gas development in Nigeria using steel pipeline infrastructures which has constituted a major problem resulting to poor domestic gas supply obligation in Nigeria. The research is based on a private sector financing model (35% equity and 65% debt) inorder to ensure efficiency and optimal utilization of the Calabar to Ajaokuta 417km critical gas pipeline infrastructure.

Acknowledgement

I thank in a special way my PhD Supervisor, Professor Adewale Dosunmu, for his detailed guidance throughout this research work. I also thank the Co-Supervisor of my PhD work, Dr. Chijioke Nwaozuzu for his positive on my research works. I am also grateful to Prof. Wumi Iledare, other lecturers, colleagues and all the administrative staff of Emerald Energy Institute, Univeristy of Port Harcourt, Port Harcourt, River State, Nigeria for their support.

I am very grateful to my lovely wife, Mrs. Awele Evelyn Henry-Biose for her encouragement and moral support. I also thank my daughters, Onyinyechukwu, Ngozichukwu and Ugochukwu for sparing me time for my research and studies. My warm appreciation to my parents, Mr. and Mrs. Martin Biose and most especially my father, who has been a source of moral support, towards academic excellence and his persistent encouragement for advanced studies.

Finally, I thank the Almighty God for his abundant grace and favours towards this academic work.

Appendices

APPENDIX A: Formulae for the calculations

1) Initial Investment Cost (IIC)

The initial investment cost for the gas pipeline is given be equation 6.1, in accordance with Shashi (2005) and the equation independent variables (expected cost of constructing gas pipeline and expected cost installing compressor station) is modified in this study, to reflect the probabilistic nature denoted by the nomenclature “expected”; While according to Mian (2011), the expected value of a decision alternative is the mean or average value per decision that would be realised, if the decision maker accepts the alternative.

$$IIC = E\,(CCP) + E\,(CCMS) + \text{Other Cost} \quad 6.1$$

Where:

E (CCP) = Expected cost of constructing /laying gas pipeline
E (CCMS) = Expected cost of installing compressor stations
Other Cost: Includes engineering and other miscellaneous cost

2) Expected Pipeline Construction Cost (CCP)

The pipeline construction cost for the gas pipeline is given by equation 6.2, in accordance with Shashi (2005). The equation is modified in this study, to reflect the probabilistic nature denoted by the nomenclature as “expected”. According to Mian (2011), the expected value of a decision alternative is the mean or average value per decision that would be realised, if the decision maker accepts the alternative.

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

E(CCP) = 0.5* (PMC + PCW+LC) 6.2

Where:

PMC = Pipe Material Cost
PCW = Cost of pipe coating and wrapping
LC = Labour cost for installing the pipeline

3) Pipeline Cost of Coating and Wrapping (PCW)

The cost for coating and wrapping cost for the gas pipeline is given by equation 6.3

PCW = PMC x 5% 6.3

4) Pipeline Material Cost (PMC)

The gas pipeline material cost is given by equation 6.4

PMC = 0.0246(D-T)*TLC 6.4

Where;
D= Outside Diameter (mm),
L= Length of the pipeline,
T= pipe wall thickness (mm) and
C = pipe material cost ($/metric ton).

5) Labour Cost (LC)

The labour cost for the pipeline construction is given by equation 6.5 and from historical data, a fixed amount is used for pipe diameter and pipeline distance and this usually $15,000 as an average labour cost (Adamu and Darma, 2017).

LC = $15,000 x diameter x length (miles) 6.5

6) Expected Cost of constructing and Installing Compressor E(CCMS)

The expected cost of constructing and installation of a compressor is given by equation 6.6. According to Menon, 2005, the unit compressor cost of $2,000 is adopted in this study considering, the intervals of 64 km and 161km to maintain high pressure in gas pipe. According to Mian (2011), the expected value of a decision alternative is the mean or average value per decision that would be realised, if the decision maker accepts the alternative.

E(CCMS) = 0.5 * ($2000*Horsepower*number of compressor) 6.6

7) Pipeline thickness (t)

The typical pipeline thickness is given by equation 6.7 in accordance with Menon (2005)

t= Do – D1/ 2 6.7

Where:
Do = Outside diameter and
Di = Inside diameter

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

8) Straight line depreciation

Straight line depreciation is adopted for the gas pipeline economic analysis and given by equation 6.8.

SV = IIC *(1-dr) lifetime 6.8

Where:
SV = Salvage value,
IIC = Initial investment cost,
dr = depreciation rate

9) Weighted Average Cost of Capital (WACC)/Capital Asset Pricing Model (CAPM)

According to Mian (2011), the weighted average cost of capital is given by equation 6.9a as follows:

WACC = (E/C) * Ke+ (D/C)*Kd (1-TR) 6.9a

Where:
E = Total value of the equity,
C = Total value of the capital
D = Total value of the debt, Ke = Cost of equity, Kd = Cost of Debt,
TR= Tax rate

Kd =r * (1-TR) 6.9b

Where:
r= prime lending rate within the Nigerian commercial banks

Ke = rf +β(rm –rf) 6.9c

Where:
rf = risk free interest rate,
rm = expected market portfolio return and

(rm –rf) = Equity Risk Premium (ERP) 6.9d

10) Discounted rate

According to Chydong et al (2010), the discount rate shall be obtained using equation 10.

Discount Rate =WACC+1% 6.10

Where:
WACC = Weighted average cost of capital

11) Uniform Capital Recovery

According to Bhattacharyya (2011), the annual amortization cost is given by equation 6.11 as follows:

 ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

$$A = P\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right] \quad 6.11$$

Where:
A = Amount of annuity required to accumulate
P = Present investment or capital expenditure
i = Interest rate
N = Number of periods
$\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right]$= Capital recovery factor

12) Volume / Capacity of Gas Pipeline

The volume and capacity is usually determined by the Weymouth formula and is given by equation 6.12.

$Q = (871)\,(d^{8/3})\,(p_1^2 - p_2^2)^{1/2}$(6.12)
$(L)^{1/2}$

Where:
Q = Cubic feet of gas per 24 hours
d= pipeline inside diameter in inches
p1 = Pressure at starting point
p2 = Pressure at ending point
L = Length of the pipeline in miles

13) Annual Gas Delivery of the Pipeline

The annual gas delivery is given by equation 6.13

= Availability factor x Annual Pipeline Capacity 6.13

- Regulated transportation cost for gas is $0.80/ Mcf
- 80% availability / utilization rate is applied

APPENDIX B: Model Assumptions for the Economic Analysis

S/N	Item Description	Value	Remark
1	Project Kick of year	2019	
2	Engineering, Procurement and Construction Period	36 months	
3	Economic Life	40 years	
4	Moratorium	years	
5	Interest Rate	18%, 20%,22%,25%& 27%	The base interest of 18% as per the 2019 lending rate and assumption to capture the long term period

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

6	Maximum Loan tenor	10 years	The maximum tenor for a long term debt financing is not more and to renewed with a new interest rate on the principal
7	Beta (β)	0.9, 0.85…	It shows or indicates the level of risk with respect to the security market line graph
8	Free Risk Rate of Return (r_f)	8%	This assumption is based on the a three month (July to September) treasury bill interest rate in the year 2019
9	Equity Risk Premium	0.11	This measures the additional compensation to the investor for taking the risk of investing in a risker project
10	Utilization factor	80%	The pipeline is assumed to be 80 percent active annually.
11	Unit Technical Cost (CAPEX)	$4, 741, 172.64 / km	AKK Business Case (2017)
12	Project financing Arrangement	Equity - 35% Debt – 65 %	

APPENDIX C: Input Data

S/N	**Data**	**Source**
1	Pipeline Length and Size	
	(A) Calabar to Enugu = 179 km, 36 inches	Nigerian National Gas Policy (2017)
	(B) Enugu to Ajaokuta = 238 km, 48 inches	Nigerian National Gas Policy (2017)
2	Pipeline Gas Volumes	
	(A) Calabar to Enugu = 1250 mmscfd (179 km, 36 inches)	Nigerian National Gas Policy (2017)
	(B) Enugu to Ajaokuta = 700 mmscfd (238 km, 48 inches)	Nigerian National Gas Policy (2017)
3	Labour Cost	
	$15,000.00 per diameter and distance	Adamu and Darma (2017)
4	Compressor Cost	
	$2,000.00 per Horsepower capacity of the compressor	Adamu and Darma (2017)
5	Prime Lending Rate (Interest Rate) in Nigeria	
	18 percent	Central Bank of Nigeria (2019)
6	Project Disocunt Rate	
	Weighted Average Cost of Capital (WACC) + 1%	Chyong et al (2010)

ISSN: 2454-1907
DOI: 10.5281/zenodo.3595283

APPENDIX D: Sensitivity Analysis of the Net Present Value

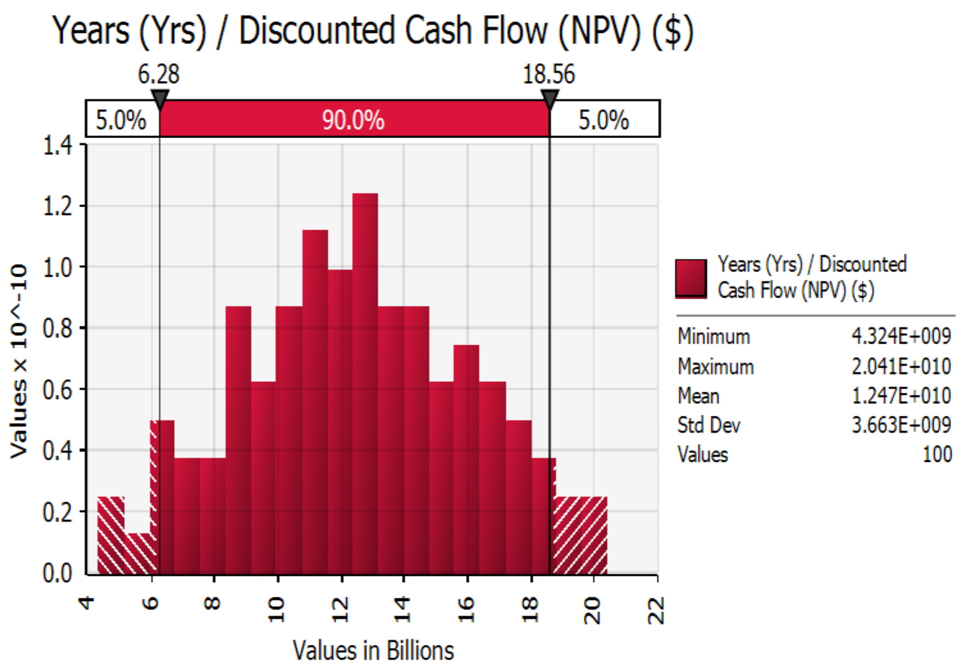

Figure 6.1: Probability density function of the NPV

References

[1] DPR, 2017 Oil and Gas Annual Report, An annual report of the Department of Petroleum Resource, Nigeria, 2017, 2 -70.
[2] Hilyard, J. F. (2012). The Oil and Gas Industry: A Non-Technical Guide, Tulsa, Oklahoma, USA, 2012, 30-35.
[3] Mian M.A, Project Economics and Decision Analysis, Vol. 1: Deterministic Models, Tulsa, Oklahoma, USA, 2011, 311-368.
[4] MPR (2017). Nigerian National Gas Policy (2017), Approved policy document prepared by Ministry of Petroleum Resource, Abuja, Nigeria, 2017, 6-85.
[5] Seba, R.D, Economics of Worldwide Petroleum Production, Third Edition, Tulsa, Oklahoma, USA, 2008, 107- 108.
[6] Carol, L. and Hudkins R. W, Advanced Pipeline Design. Retrieved 3rd August, 2019 fromhttp://www.ou.edu/class/che-design/a-design/projects2009/Pipeline%20Design.pdf (2010)
[7] Odunuga J., Green and Brown Field Development (2016)1-33
[8] Baru M. Retrieved from Guardian Newspaper Nigeria Announces Policy to end gas flaring in two years, 2018
[9] Ahmed, A. and Dsarma, M. R., Economic Analysis of Gas Pipeline Projects in Nigeria, Journal of Economics and Sustainable Development, Vol. 8, No.2, www.iiste.org, 2017, 39 -67

*Corresponding author.
E-mail address: harios2003@ yahoo.com