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Original Article

Multi-objectives regression, optimization and risk assessment of profitability indicators of the simulation of mini Liquefied Petroleum Gas (LPG) dispensing unit

Kazeem Kolapo Salam[a,]*, Kehinde Ayoola Babatunde[a], Akeem Olatunde Arinkoola[a], Titilayo Deborah Oluwole[b], Dolapo Aremu[a], Usman Olalekan Oladapo[a], And Suliyat Omolara Ibrahim[a]

[a]*Department of Chemical Engineering, P.M.B. 4000, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria*
[b]*Department of Chemical Engineering,, Louisiana State University, Baton Rouge, LA 70803, USA*

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ABSTRACT

In this study, simulation of a mini Liquefied Petroleum Gas (LPG) dispensing unit was conducted using ASPEN HYSYS and the operation of both compressor and pump were validated theoretically. The effect of the economic parameters (Total Annual Sales (TAS), Total Production Cost (TPC), Fixed Capital Investment (FCI) and interest rate (r)) on the behaviour of three profitability indicators (Net Present Value (NPV), Return on investment (ROI) and Internal Rate of Return (IRR)) were modelled and optimized using Box Behnken Design (BBD). The uncertainty of the developed models was determined using Oracle Crystal Ball (ORB). The optimum economic parameters, TAS of ₦48,830,600, FCI of ₦37,422,000, TPC of ₦35, 053,000 and r of 5.4% predicted optimum profitability indicators are ROI of 34.6%, NPV of ₦98,993,580.25 and IRR of 34.15% for 15 years' investment plan. An interaction of the economic parameters showed that for NPV to be positive, TAS value should be greater than ₦42.5 million and the TPC should be less or equal to ₦36 million. The profitability analysis suggested that this investment will pay back in 2.36 years. Given that the demand of LPG is on the increase and therefore, this LPG plant will be a long term investment with a good return on investment.

1. Introduction

Natural Gas is one of the cleanest, safest and efficient energy of all energy sources. LPG, an extract from natural gas is used as fuel for different purposes such as fuel for vehicles, cooking (and heating appliances), refrigerant and aerosol propellant[1], [2]. Nigeria despite been one of the top 10 largest producer of crude oil and its associated gas [3], a large percent of domestic cooking still depends on traditional fuel as their source of energy which is not only hazardous to the user, but it also degrades the environment. Natural gas dissolved in crude oil is produced alongside the crude oil during the latter's exploration [4], [5]. Liquefied Petroleum Gas containing iso-propane (i-C3) and iso-butane (i-C4) is extracted from the Natural Gas liquids by fractionation or distillation [2], [6].

One of the benefits of utilizing natural gas as a source of fuel both for domestic and industrial purposes is that it will reduce gas flaring[7]. Flaring of gas gives rise to the emission of carbon dioxide (CO_2) which leads to global warming. Another environmental consequence of gas flaring is the formation of acid rain [5]. In 2010, Unicef approximated the economic value of the gas burned by flaring to be worth \$2.5 billion per annum. Given that the Nigerian economy depend more on the Petroleum sector, allowing for more utilization of LPG aid in the

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* *Corresponding author.* Tel.: 2347034384645
E-mail address: kksalam@lautech.edu.ng

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development of the gas sector and generation of more revenue[7]. An estimate of 1.5 million premature deaths per annum has been attributed to the use of biomass as source of fuel. Recently with the increase in awareness on the health effect of traditional fuel (wood burning) for cooking, the demand for LPG for cooking has been on the rise [8].

Construction of an LPG dispensing plant will not only aid in the effective distribution of LPG to the community but will result in creation of more jobs for rural and urban dwellers, growth in the GDP (gross domestic product) of the country, improvement in national productivity and, conservation of trees that would have been felled for cooking purposes while promoting cleaner and more efficient fuel for cooking in Nigeria [9]. Despite positive response of users to using LPG, scarcity of LPG at dispensing units, lack of funds, high cost of refilling, fear of fire outbreak (due to the use of substandard accessories and over pressuring of gas cylinder) and distribution across various dispensing units are some of the identified problems hindering the low patronage of the use of LPG [10], [11]. Despite these increase in the consumption of LPG over the years, the consumption capacity is still below 20% of the total LPG produced per year in Nigeria.

Simulation, a model validation tool is necessary before an existing system is altered or a new one is built to prevent wrong utilization of resources available, allows the systems to be built or altered to desire specifications and to prevent or reduce unforeseen bottlenecks [12]. Simulation has certain advantages over mathematical model in that it allows for insight into certain management problems, it helps to deduce important variables in the system and the relationship between them. Aspen HYSYS is a leading process simulation and modeling tool with a demonstrated record of providing a massive economic benefit throughout the process engineering lifecycle. It combines the power of process simulation and optimization to the engineering desktop and delivers an uncommon combination of modeling technology and ease of use[13].

Chemical processed are complex set of reactions that are simplified by development models that can mimic the chemical process either through the constitutive equations that guide the process or the use of data generated from the operation of the process (empirical or regression models). Design of Experiments (DOE) is a statistical too for studying the relationship between the input variables and output of the model without any accompanying limitation where satisfactory results are recorded when applied[14]. Of the different methodology in DOE, the response surface methodology (RSM) is most often used of which its box behnken design (BBD) has been widely used for optimization of process parameters as it an independent quadratic design that has proven to be more effective, requires the least number of trials and has a higher efficiency compared to other designs[15], [16]. Models which are a simplification of a real systems have the tendency to introduce uncertainties in to the system in the form of bias or errors[17]. An uncertainty analysis is therefore necessary so as to enable the confidence in the result or in the inference/decision made from the models to be expressed and also enable a better understanding of the limitation of the model developed[18], [19].

Investigations from different sources supported that the use of LPG as a source of energy will among other benefits promote a cleaner environments and source of revenue for government if properly harnessed. Distribution network, short supply and safety concerns are some of the conditions that prevented smooth distribution of this energy. Therefore, this study simulates a mini-LPG dispensing plant with the aid of ASPEN HYSYS using real data from a dispensing plant with the aim of determining the economic feasibility of this project in a populated town in Nigeria.

2. Materials and Methods

2.1. Simulation and Modeling Tools

The simulation of the plant was conducted using ASPEN HYSYS Software. This design was based on a mini dispensing unit located in Ibadan, Nigeria. The capacity of this station is 67000 litres (3.4 ton). The operating pressure is 220 kPa and the temperature is 20 ^{o}C. The frequency of refill at this station was between 2 and 3 times in a month. This investigation considered a worst case scenario of 2 refilling cycle in a month and a total of 24 times in a year and a year is considered to contain 50 weeks (320 days). The line from the lorry was connected to a tank from where LPG that exists in both vapour and liquid phase was transported through both compressor (with adiabatic efficiency of 75%) and pump to a mixer. The process stream data was presented in Table 1 at the inlet to the tank and the design of the major components in the simulation was presented in Figure 1. The tank has an allowable pressure of 1.56 mPa and maximum temperature of 40 ^{o}C. The LPG line was splitted into three dispensing units where retailers' cylinders were filled up. The three outlets are designed based on the company specification and the flowchart of the plant was presented in Figure 2. The designed compressor and pump are validated by comparing their theoretical values with simulated values of their polytrophic head and pump head respectively.

2.2. Project and Cost Evaluation

An estimate of the investment and the cost of production are needed to be calculated before the profitability of any project can be assessed[20]. The total investment for any process consists of FCI for physical equipment and facilities in the plant and working capital which must be available to pay salaries and wages of the staffs, to make raw materials continuously available and products on hand, and to handle other special items requiring a direct cash outlay [21]. The Association for the Advancement of Cost Estimating International (AACE International) classifies capital cost estimates into five types according to their accuracy and purpose[22]. The Preliminary estimate method (budget authorization estimate) was utilized for this research because of its probable accuracy of ±20 percent[21], [23]. Factors such as sources of equipment, price and wage fluctuations, government and company policies, and the operating time, rate of production and sales demand may be responsible for this variation [21].

2.2.1. Fixed Capital Cost/Investment

The FCI represents the capital spent on the installation of process equipment with all auxiliary components that are needed for complete process operation. Expenses such as for piping, instruments, insulation, foundations, and site preparation are examples of costs included in the fixed-capital investment[21].

2.2.2. Cost Index

A cost index is an index value for a given point in time showing the cost at that time relative to a certain base time. The most common of these indexes are the Marshall and Swift all-industry and process-industry equipment indexes, the Engineering News-Record construction index, the Nelson-Farrar refinery construction index, and the Chemical Engineering plant cost index. Construction costs for chemical plants form the basis of the Chemical Engineering plant cost index[21]. The Chemical Engineering Plant Cost Index (CEPCI) and Marshall & Swift Process Industry Index (MSPII) are the two commonly used indexes to update the purchasing cost of equipment in time[24], [25]. The Chemical Engineering Plant Cost Index was used for the calculations done in this work. A composite index for the United States process plant industry is published monthly in the journal of Chemical Engineering, the CPE plant cost index.

2.2.3. Estimation of Purchased Costs of Equipment (PCE)

The identified major equipment from the flow sheet are Compressor, pump, 2-mixers, 2-storage tanks and 3-dispensers. The cost of the purchased equipment was determined using the factorial method of cost estimation. The recent cost of similar equipment was searched online dated back to 2014 from the websites. The cost index for 2021 (C_{I21}) and 2014 (C_{I14}) are 761.5 and 576.1. Cost of equipment was researched online (http://www.matche.com/equipcost and http://mhhe.com/engcs/chemical/peters/data/) while price of dispenser was obtained from Alibaba.com. The cost was then escalated to the current price using the Sept 2021 CE index of 761.5 and the PCE for this study estimated from equation 1 was tabulated in Table 2.

$$C_{21} = C_{14} * \frac{C_{I21}}{C_{I14}} \rightarrow \quad C_{21} = C_{14} * 1.3218 \qquad (1)$$

Where: C_{21} is the actual cost in 2021, C_{14} is the cost in 2014, C_{I14} is the 2014 cost index, and C_{I21} is the 2021 cost index.

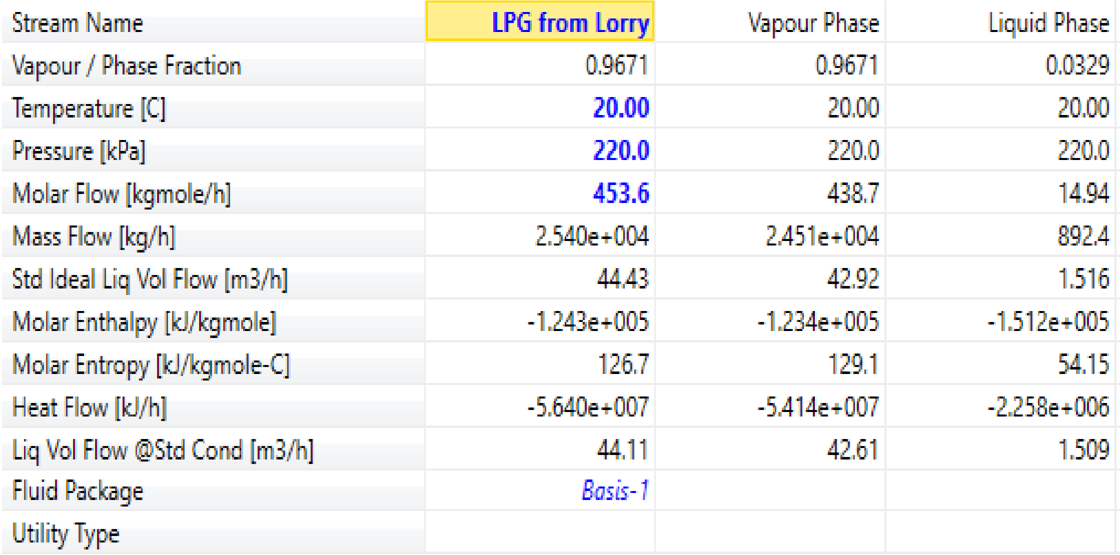
2.2.4. Working Capital (WC)

Working Capital (WC) is the additional money needed, above what it cost to build the plant, to start the plant up and run it until it starts earning income [21]. A typical figure of the working capital for petrochemical plants is 15 per cent of the fixed capital[20].

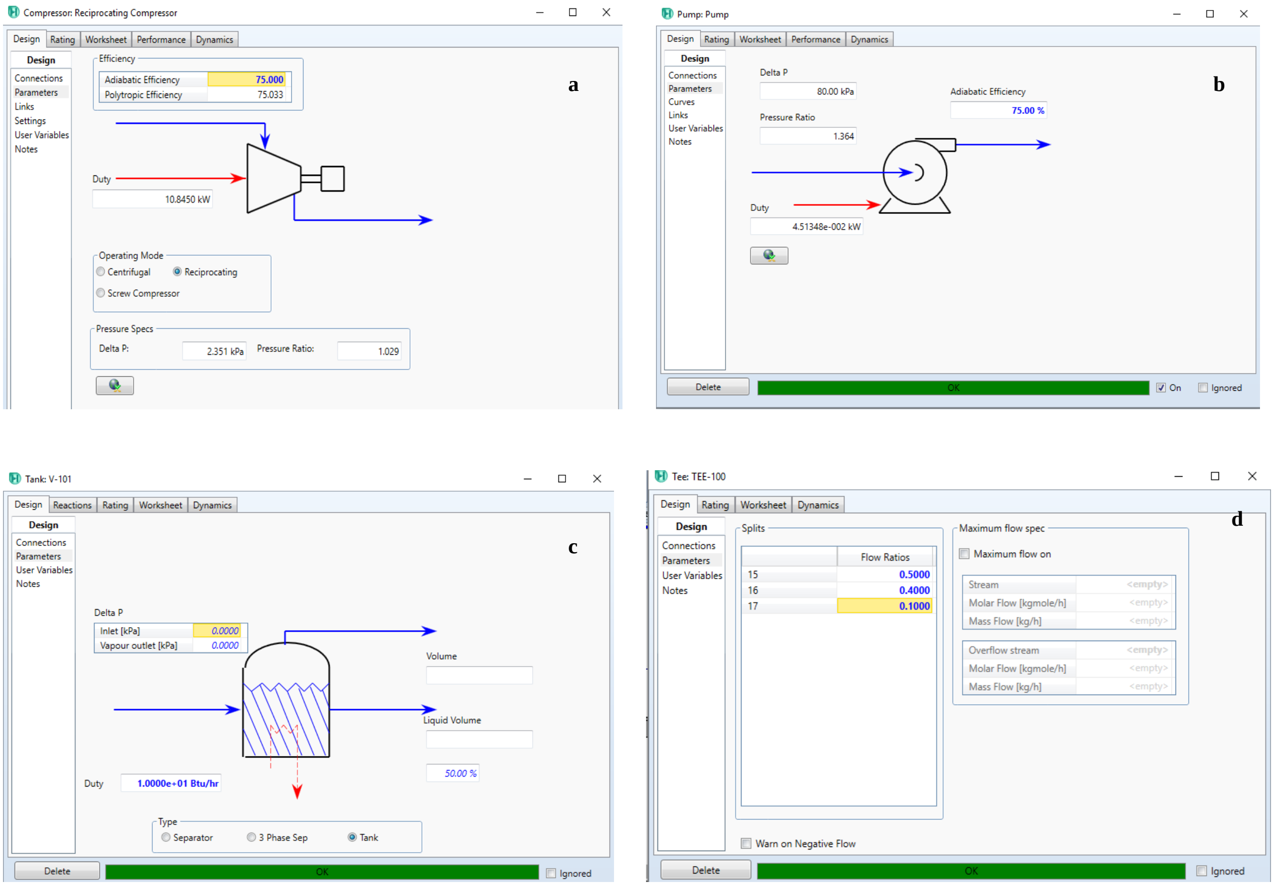
2.2. Total Capital Investment (TCI)

The total investment needed for a project is the sum of the fixed and working capital[26]. Table 3 shows the components involved in calculating the FCI, WCI and TCI.

Table 1: Feed stream parameters



Stream Name	LPG from Lorry	Vapour Phase	Liquid Phase
Vapour / Phase Fraction	0.9671	0.9671	0.0329
Temperature [C]	20.00	20.00	20.00
Pressure [kPa]	220.0	220.0	220.0
Molar Flow [kgmole/h]	453.6	438.7	14.94
Mass Flow [kg/h]	2.540e+004	2.451e+004	892.4
Std Ideal Liq Vol Flow [m3/h]	44.43	42.92	1.516
Molar Enthalpy [kJ/kgmole]	-1.243e+005	-1.234e+005	-1.512e+005
Molar Entropy [kJ/kgmole-C]	126.7	129.1	54.15
Heat Flow [kJ/h]	-5.640e+007	-5.414e+007	-2.258e+006
Liq Vol Flow @Std Cond [m3/h]	44.11	42.61	1.509
Fluid Package	Basis-1		
Utility Type			



Compressor: Reciprocating Compressor

Efficiency
Adiabatic Efficiency 75.000
Polytropic Efficiency 75.033
Duty 10.8450 kW
Operating Mode
○ Centrifugal ● Reciprocating
○ Screw Compressor
Pressure Specs
Delta P: 2.351 kPa Pressure Ratio: 1.029

Pump: Pump

Delta P 80.00 kPa
Pressure Ratio 1.364
Adiabatic Efficiency 75.00 %
Duty 4.51348e-002 kW
☑ On ☐ Ignored

Tank: V-101

Delta P
Inlet [kPa] 0.0000
Vapour outlet [kPa] 0.0000
Volume
Liquid Volume
50.00 %
Duty 1.0000e+01 Btu/hr
Type
○ Separator ○ 3 Phase Sep ● Tank
☐ Ignored

Tee: TEE-100

Splits

	Flow Ratios
15	0.5000
16	0.4000
17	0.1000

Maximum flow spec
☐ Maximum flow on
Stream <empty>
Molar Flow [kgmole/h] <empty>
Mass Flow [kg/h] <empty>
Overflow stream <empty>
Molar Flow [kgmole/h] <empty>
Mass Flow [kg/h] <empty>
☐ Warn on Negative Flow
☐ Ignored

Figure 1. Design of components in the simulation. Compressor (a), pump (b), tank (c) and tee joint (d)

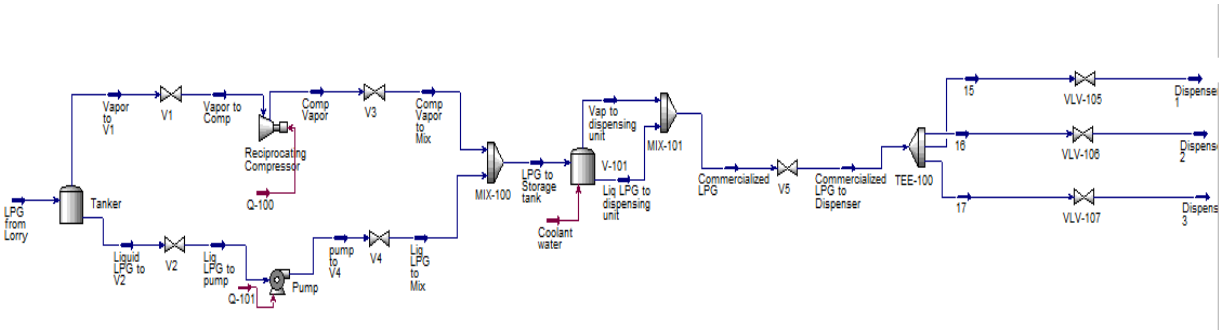


Fig 2. Process Flow Diagram of the LPG Dispensing Plant

Table 2: PCE of Equipment in the Flow sheet

S/No	Equipment	Description of equipment	C_{14}	C_{21} (PCE)
1	Compressor	1000 psi carbon steel Reciprocating compressor with a power of 10.845 kw	16200	21416
2	Pump	cast iron horizontal mechanically sealed pump discharged at of 1.5 inch	2200	2908.4
3	Mixers (2)	1.5 inch Carbon steel motionless mixer with Internal pressure of 25 psi	479	1266.476
4	Tanks (2)	6700 litre (1769.953 US gallon) Carbon steel tank	2600	6874.4
5	Dispenser (3)	LPG dispensing pumps		16,500
	Total cost in ($)			48,965.276
	Total cost (₦ (**₦415.72/$)**			20,355,844.54

2.3. Profitability Indicators Analysis

The following key profitability indicators were calculated to determine the feasibility study of the project. The Gross and Net Profit, Payback period, Net Present Value (NPV) and the Rate of Return (ROR), as presented in Table 4 [20], [22]. The price of LPG was estimated as $741.2 per MT in Nigeria (www.lpginnigeria.com). At Retail Price, 20 ton of LPG cost ₦11 million and therefore, the price of LPG per tonne is ₦550,000 per tonne. The capacity of the plant is 6700 litre of LPG which is equivalent to 3.4 tonne and LPG was discharged twice a month based on the field operation of the plant. A plant life of fifteen (15) years was selected for this profitability analysis.

2.4. Design and Optimization of Profitability Indicators

The cost of commodities is generally not stable currently and this will obviously affect economic indices and profitability estimates of the LPG dispensing plant. The considered profitability indicators are NPV, ROI and IRR with the principles guiding applying them was reported in the literature[27]. From the determination of revenue and expenses of the plant, the values of TAS, TPC, FCI and interest rate (r) were varied as tabulated in Table 5 while the three profitability parameters are the responses. These multi-objectives design was implemented using BBD. A total of 29 experimental runs were generated and used for the modelling and optimization of profitability indicator that will favour LPG plant for a period of fifteen (15 years) was established.

Table 3: TCI and APC of the LPG plant

Summary of Production Cost	
Cost	Description of Expenses
Variable Cost	
Raw Material Cost	At refinery price of ₦310,000 per ton
Total Variable Cost	
Fixed Cost	
Maintenance	5% of Fixed Capital
Operating Labour	From Minimum Wage
Plant Overheads	50% of Operating Labour
Total Fixed Cost	
Direct Production Cost	Variable +Fixed Cost
Total Production Cost	Variable +Fixed Cost
Total Capital Investment (TCI)	
Cost	Description of Expenses
a. Purchased Cost of Equipment (PCE)	100%
b. Installation	30% of PCE
d. Buildings	5% of PCE
c. Piping	25% of PCE
d. Site Development	5% of PCE
Physical Plant Cost (PPC)	summation of a-d
e. Contractors Fee	3% of PPC
f. Contigency	5% of PPC
Indirect Plant Cost (IPC)	summation of e & f
FCI	PPC+IPC
WCI	5% of FCI
TCI	FCI+WCI

Table 4: Profitability Indicators.

S/No	Indicators
1	$PayBack\ period = \frac{Total\ Investment}{Annual\ Cash\ Flow}$
2	$NPV = \sum_{n=1}^{n=t} \frac{C.F_n}{(1+r')^n}$
3	$ROR = \frac{Cummulative\ net\ cash\ flow}{life\ of\ project \times original\ investment} \times 100$
4	$IRR = \sum_{n=1}^{n=t} \frac{C.F_n}{(1+r')^n}$

Where $C.F_n$= cash flow in year (n); t= project life in years and i = interest rate.

Table 5: Techno-Economic variables used for design and optimization study

Factors	Units	low	Mid	High
FCI	$(*10^6)$ ₦	39.29	41.16	43.04
TPC	$(*10^6)$ ₦	35	36	37
TAS	$(*10^6)$ ₦	40.8	44.88	48.96
r	%	5	12.5	20

2.5. Risk Assessment

Risk assessment or Uncertainty analysis was conducted on the effect of the economic parameters in Table 5 on the profitability indicators using Monte Carlo Simulation (MCS) so as to determine the risk associated with the prediction of the techno-economic variables in Table 5. Oracle Crystal Ball (ORB) was the statistical method used by MCS to perform uncertainty analysis, sensitivity studies and risk assessment[28], [29]. The number of trial used for the simulation was 100, 000. Assumption that fits into each of the variables declared in Table 5 was selected from the MCS environment while the distribution that fit into the three responses were respectively forecasted after the simulation.

3. Results and Discussion

3.1. Validation of Selected Components Used for the Simulation

With reference to the technical specification of feed stream, it was discovered that the vapour phase fraction has higher fraction of 0.9671 than the liquid phase of 0.0329 which resulted in incorporating a centrifugal pump for the liquid phase and reciprocating compressor for the vapour phase.

In Figure 3, the stream of the simulated LPG dispensing plant was tabulated. Ideal adiabatic efficiency of 75% was specified before the simulation was initiated (Figure 3a). Sensitivity analysis was conducted on adiabatic efficiency specified with the aim of getting a reciprocating compressor power consumption rate greater than 10 kw for efficient discharge of LPG. This was specified in conjunction with consumption rate to mimic the specified conditions used in-house for the design of the compressor used by this mini plant. An ideal adiabatic efficiency yielded a power consumption rate of 10.84 kw as shown in Figure 3.

For the validation of the reciprocating compressor design, the simulated polytropic efficiency was 75.003, an adiabatic and polytropic exponent of 1.081 and 1.1183. A relationship that linked polytropic efficieny (η_a) with both adiabtatic and polytropic exponent(n) from adiabatic (k) and polytropic head was expressed in equation 3 [30].

$$\frac{n-1}{n} = \frac{k-1}{k} * \frac{1}{\eta_a} \tag{3}$$

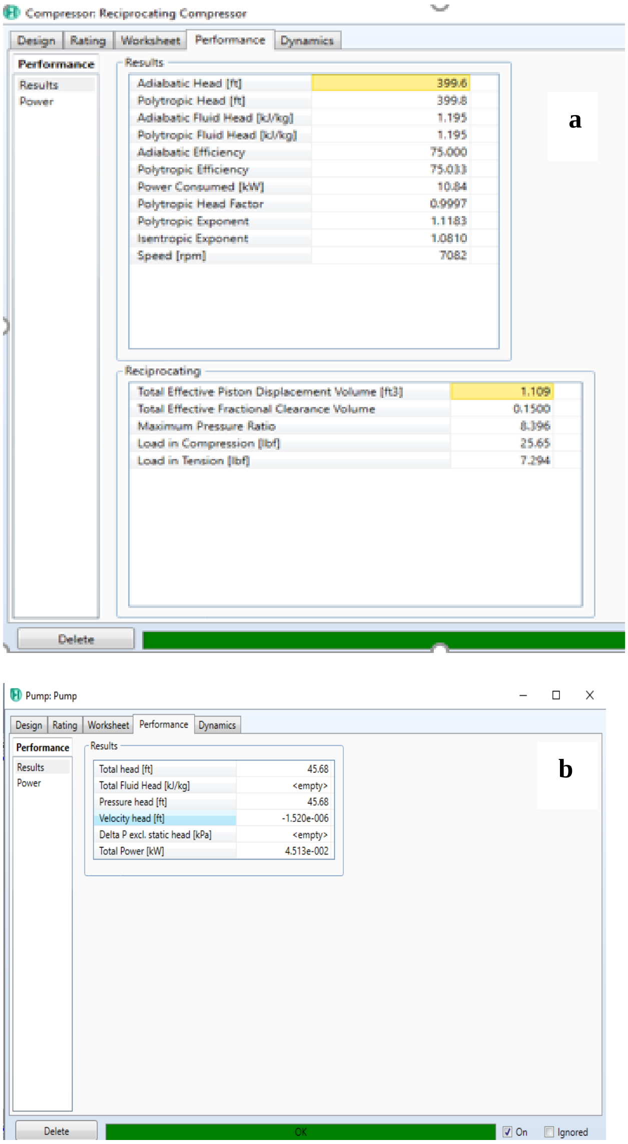
From equation 3, the theoretically calculated polytrpic efficiency was 71.8% while the simulated polytropic efficiency was 75.003 %.

For the pump used in the simulation, it was discovered that the total pump head for the LPG discharge was 45.68 (Figure 3b) which is approximately equal to the theoretical calculation of 45.57 (from equation 4).

$$\text{Total head for centrifugal pump(ft)} = \frac{\text{Pressure drop(psi)}\times 2.31}{\text{Specific gravity}} \tag{4}$$

Since 14.7 psi=101.325 kPa, therefore Pressure drop equals 80 kPa which is equivalent to 11.6 psi. Also Specific gravity of LPG equals 0.588.

$$Total\ head(ft) = \frac{11.6\times 2.31}{0.588} = 45.57ft \tag{5}$$



Results

Adiabatic Head [ft]	399.6
Polytropic Head [ft]	399.8
Adiabatic Fluid Head [kJ/kg]	1.195
Polytropic Fluid Head [kJ/kg]	1.195
Adiabatic Efficiency	75.000
Polytropic Efficiency	75.033
Power Consumed [kW]	10.84
Polytropic Head Factor	0.9997
Polytropic Exponent	1.1183
Isentropic Exponent	1.0810
Speed [rpm]	7082

Reciprocating

Total Effective Piston Displacement Volume [ft3]	1.109
Total Effective Fractional Clearance Volume	0.1500
Maximum Pressure Ratio	8.396
Load in Compression [lbf]	25.65
Load in Tension [lbf]	7.294

Results

Total head [ft]	45.68
Total Fluid Head [kJ/kg]	<empty>
Pressure head [ft]	45.68
Velocity head [ft]	-1.520e-006
Delta P excl. static head [kPa]	<empty>
Total Power [kW]	4.513e-002

Fig 3. Simulation performance result of the compressor and pump.

The effect of molar flow of LPG on Compressor and pump power was presented in Figure 4(a and b). There was linear increase in both powers with respect to the increase in the molar flow of LPG from the lorry from 0 to 1000 kmole/h. Compressor power increased from 2.5

to 24 W, while pump power increased from 0.01 to 0.1 W. For effect of vapour pressure on the power of both the compressor and pump was presented in Figure 4(c & d). The compressor power increased from 0 to 1000 W with increase in vapour pressure from 100 to 1000 kPa while pump power increased from 0 to 0.45 W.

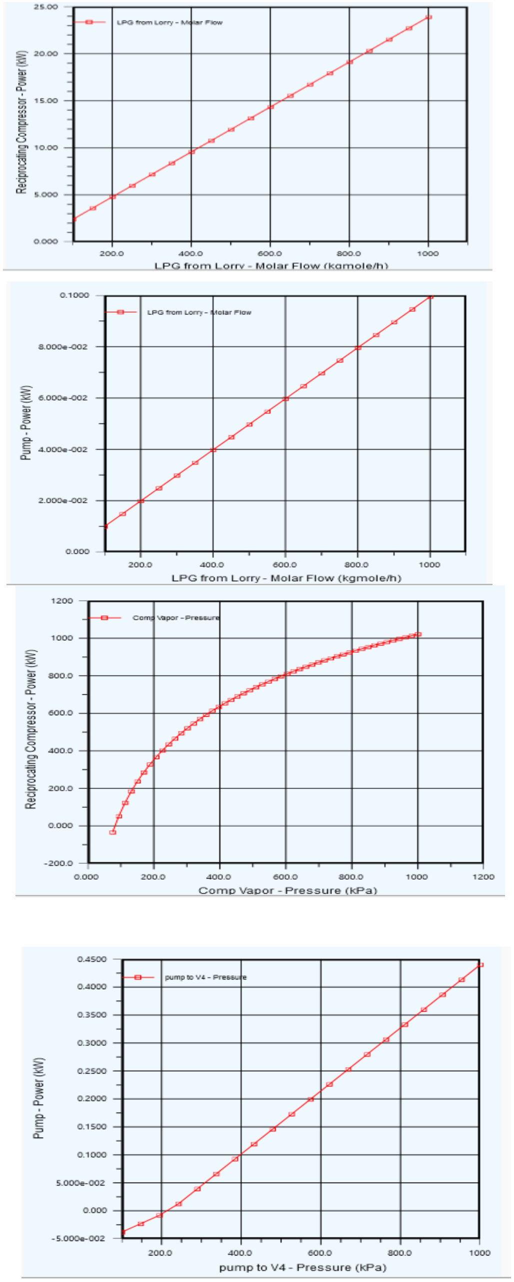


Fig 4. Effect of vapour pressure and molar flow on both compressor and pump power.

3.2. Results of the Profitability Indicator Analysis

3.2.1. Parameters Interactions of the Profitability Indicators

The effect of each of the four selected techno-economic variables on the three profitability indicators NPV, ROI and IRR was presented in Figure 5. This plot is called perturbation plot. The value of one parameter is increased at a time while the values of other variables are kept constant at their mid points respectively. In Figure 6a, increase in A positively affected NPV while increase in B, C, and D decreased NPV value. At low A, NPV was in deficit and for NPV to be positive, A value should be greater than ₦42.5M. The maximum NPV of ₦51M was recorded at low D. For individual behavior of variables on ROI, A is the most influential parameter that favor ROI. Increase in A gave rise to a maximum ROI of 31.52% at ₦49M. Increase in B and C slightly reduced the value of ROI from 24.02 to 19.15 and 22.62 to 20.65 while D has no effect on ROI of the LPG dispensing plant. The influence of the variables on IRR was similar to the plot generated for ROI. Parameter A was the most influential to IRR, Increase in B and C slightly decreased the IRR value while D has no effect on IRR.

Interaction between the main terms that are significant to developed models for NPV, ROI and IRR was presented using surface plots in Figure 6 (a-f). Figure 8a&b are the effect of interaction between different main terms on NPV. In Figure 8a, increase in D from 5 to 20% decreased the value of NPV from ₦11.09M to a deficit NPV of 16.29M. For a low D, NPV increased from 11.09 to 90.93 when A was increased from 41 to ₦49M. While at high D, the LPG dispensing plant will only be in profit at A greater than ₦45M. At high A (₦49M), the difference between NPV for low and high D was ₦73.93M. Increase in B regardless of D decreased NPV under the interaction of BD as shown in Figure 8b. The highest NPV of 60.8 was recorded at a low B and D respectively. For NPV to be a positive value, B should be less or equal to ₦36 M while NPV is in the positive zone for all values at low D. Interactions of main terms for ROI and IRR are presented in Figure 6(c & d) and Figure 6(e and f) respectively.

3.2.2. Regression Analysis

The equation developed for the three profitability parameters NPV, ROI, and IRR with respect to the four input parameters such as FCI, TPC, TAS and, r are presented in equations 6, 7 and 8 respectively. The correlation coefficient (r^2) values of the three models are 0.998 for NPV, 1 for ROI and 0.995 for IRR respectively. The predicted and adjusted R^2 of the three models 0.997/0.994, 1.00/1.00 and 0.999/0.999 for NPV, ROI and IRR respectively.

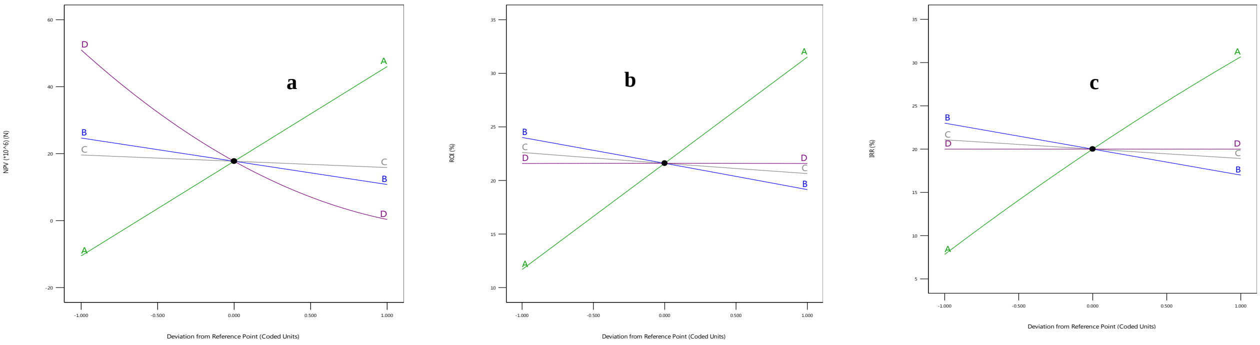


Fig 5. Perturbation plot of (a) NPV, (b) ROI and (c) IRR

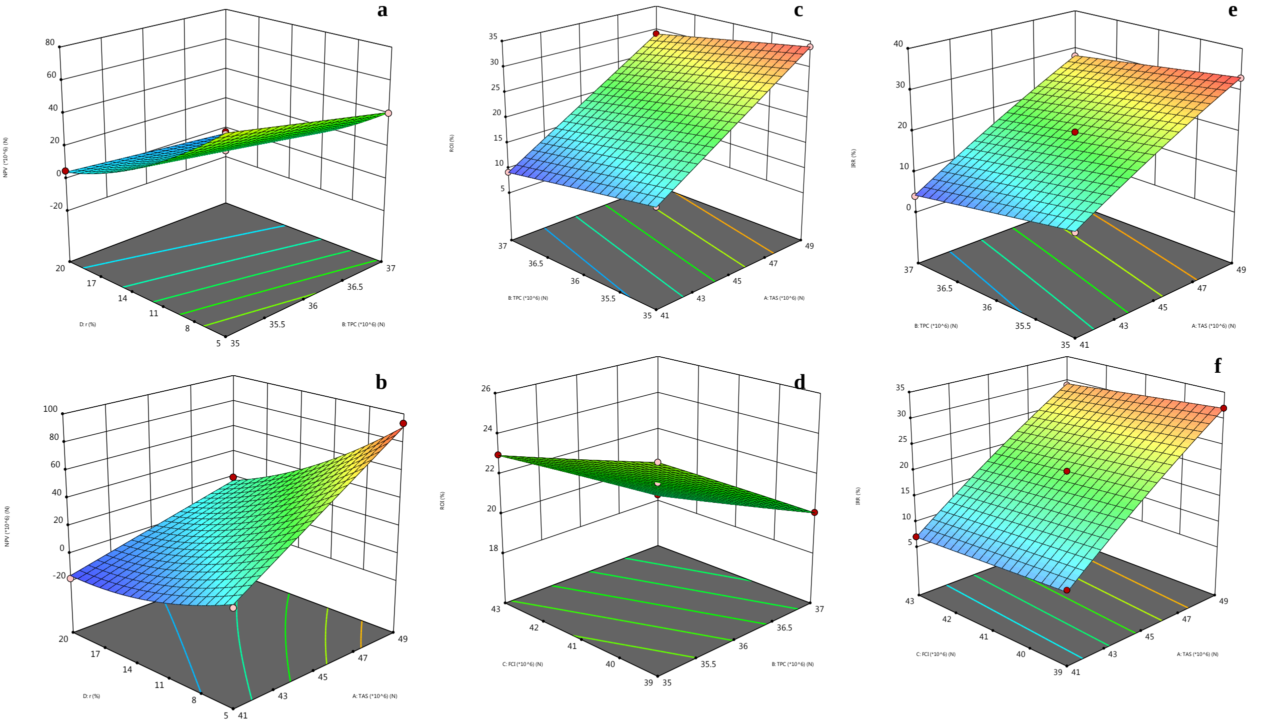


Fig. 6. Surface plots of NPV, ROI and IRR.

Table 6: ANOVA table for the three profitability index considered.

NPV			ROI			IRR		
Source	**F-value**	**p-value**	**Source**	**F-value**	**p-value**	**Source**	**F-value**	**p-value**
Model	1438.8	< 0.0001	**Model**	2.55E+05	< 0.0001	**Model**	5798.65	< 0.0001
A-TAS (*10^6)	5108.27	< 0.0001	A-TAS (*10^6)	2.38E+06	< 0.0001	A-TAS (*10^6)	37538	< 0.0001
B-TPC (*10^6)	307.71	< 0.0001	B-TPC (*10^6)	1.43E+05	< 0.0001	B-TPC (*10^6)	2592	< 0.0001
C-FCI (*10^6)	22.54	0.0001	C-FCI (*10^6)	23378.57	< 0.0001	C-FCI (*10^6)	338	< 0.0001
D-r	4097.32	< 0.0001	D-r	0	1	D-r	0	1
AD	288.35	< 0.0001	AB	5.04	0.0384	AB	24	< 0.0001
BD	17.32	0.0005	AC	1818.4	< 0.0001	AC	6	0.0236
D^2	230.1	< 0.0001	BC	45.33	< 0.0001	A^2	92.57	< 0.0001
			B^2	6.17	0.0237			
			C^2	10.2	0.0053			
			D^2	6.17	0.0237			

TABLE 7. Summary of the Economic Analysis

Parameter	Cost
FCI, ₦	37422000
WCI, ₦	2431300
TCI, ₦	39853300
TPC, ₦	35053000
TAS (Revenue), ₦	48,830,600.00
Price of LPG, ₦	550000
Interest rate, %	5.44
Gross Profit (GP), ₦	13,777,600.00
Simple Payback time, year	2.893
ROI, %	34.6
NPV, ₦	98,993,580.25
IRR, %	34.15%
Life of plant, year	15

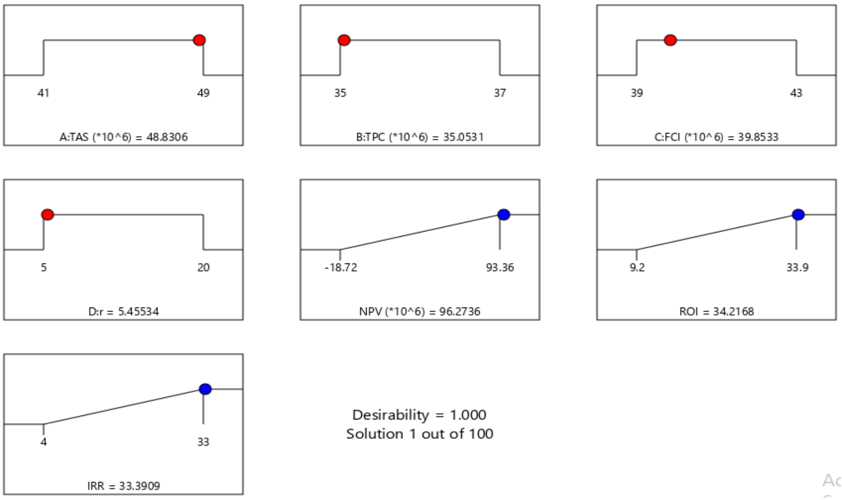


Fig. 7. Summary of the Optimized predicted conditions and the corresponding profitability indicators.

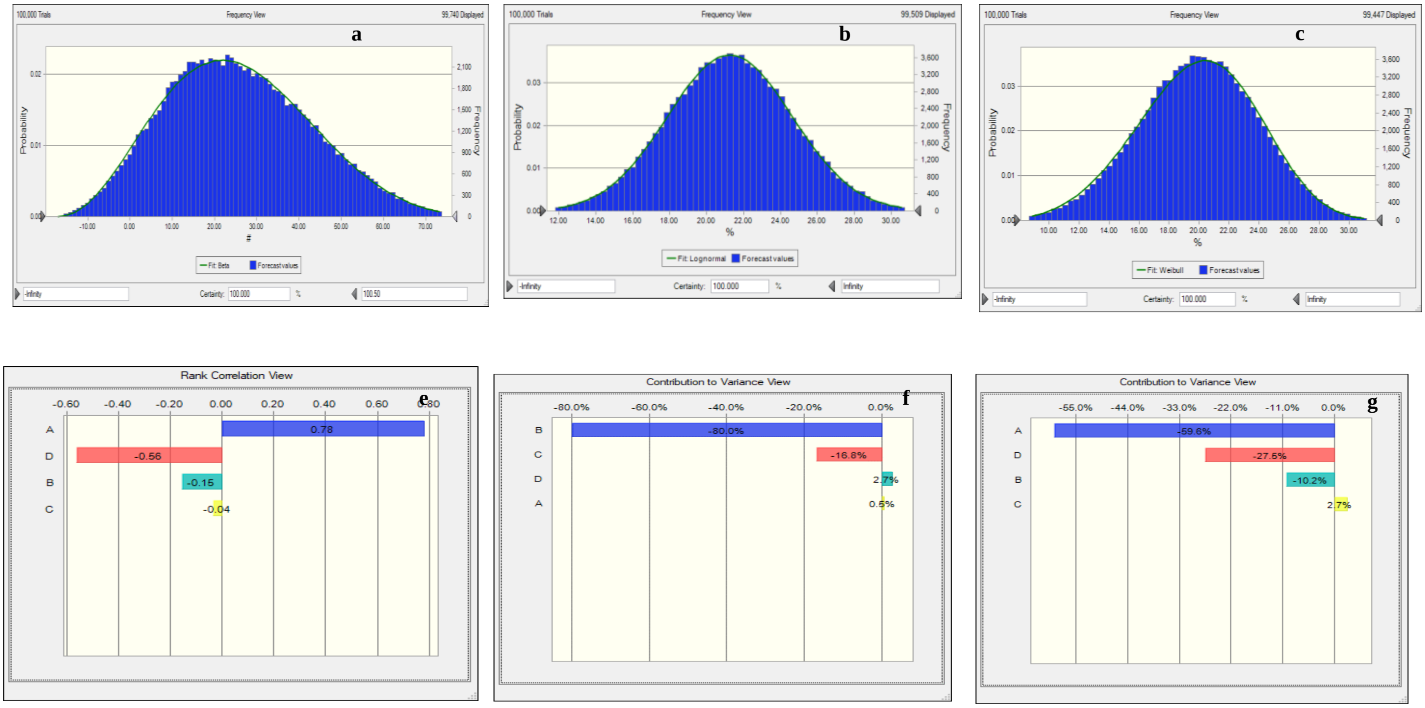


Fig. 8. Frequency distribution (a to c) and correlation (e to g) of the variables used for the models developed.

The Adjusted and predicted values of the three models supported the accuracy of the developed models due the difference of their respective adjusted and predicted R^2 that was less than 0.2. Analysis of Variance (ANOVA) table of the three models was tabulated in Table 6.

$$NPV = 5.18326 + 11.91896 * TAS - 11.695 * TPC - 0.939167 * FCI - 3.14164 * r - 0.387917 * TAS * r + 0.380333 * TPC * r + 0.141156 * r^2 \quad (6)$$

$$ROI = -42.86415 + 4.68854 * TAS - 2.67708 * TPC + 0.253646 * FCI + 0.009722 * r + 0.006250 * TAS * TPC - 0.059375 * TAS * FCI + 0.037500 * TPC * FCI - 0.021875 * TPC^2 + 0.007031 * FCI^2 - 0.000389 * r^2 \quad (7)$$

$$IRR = +71.69271 + 3.85417 * TAS - 8.62500 * TPC + 0.864583 * FCI - 1.70837\mathrm{E} - 17 * r + 0.125 * TAS * TPC - 0.031250 * TAS * FCI - 0.046875 * TAS^2 \quad (8)$$

In this analysis, a p-value less than 0.05 signifies that the model term is a significant term to model developed. The three models developed are reduced quadratic models that have main, interactive and quadratic terms. The model terms of NPV comprised of four main (A, B, C & D), two interactive (AD & BD) and one quadratic (D^2) terms in which all are significant model terms for the prediction of NPV of LPG dispensing plant. In the case of ROI, four main (A, B, C & D), three interactive (AB, AC & BC) and three quadratic (B^2, C^2 & D^2) terms were used for its model developed. All model terms except D are significant model terms. For IRR too, all the model terms except D are significant model terms. The optimized predicted condition for NPV, ROI and IRR was shown using Ramp of optimization (Figure 7). Desirability function was used to ranked the optimized predicted outputs for each of the profitability indicators using the developed regression models in equation 6, 7 and 8. The accuracy of the validation of the prediction computed using percentage deviation. The validated values under predicted the optimized values by 2.83, 1.17 and 1.83% for NPV, ROI and IRR respectively.

The LPG plant under consideration has the capacity to discharge. The techno-economic analysis suggested that this investment will pay back in 2.36 years with a ROI of 34.15% (Table 7). The NPV of this investment plan is ₦98 M while its IRR is 34.6 at an interest rate of 5.4%. The demand of LPG is on the increase and also the price of LPG is on the upward trend, therefore, this LPG plant in a suitable place is a long term investment with a good.

3.2.3. Uncertainty Analysis

The certainty level and rank coefficient of the multi-objectives predictive models for the NPV, ROI and IRR was presented in Figure 8. For each of the responses considered, 100, 000 trials were performed for MCS. The uncertainty plot of the three responses are presented in Figure 8(a, b and c) while the rank coefficient was presented in Figure 8 (e, f, and g). From Figure 8 (a, b and c) the uncertainty values of the responses are 100% while the fitted distributions of each of these predictions are Beta, Lognormal and Weibull for NPV, ROI and IRR.

The implication of the uncertainty values recorded was the ability of the developed models to predict each response within the specified experimental design (Table 5). The rank coefficient of the variables on each of the model developed was presented in Figure 8 (e, f and g). For NPV, the most influential variable was A (78%), followed by D (56%), B (15%) and C (4%) in decreasing order. For ROI, B (80%) has the most influential effect of the developed model. The identified influential variables for the three models from uncertainty analysis are similar to the identified variables from ANOVA analysis using BBD analysis.

4. Conclusion

From the simulation of mini LPG dispensing unit, it was deduced that:

- ✓ the optimum profitability indicators ROI of 34.6%, NPV of ₦98,993,580.25 and IRR of 34.15% were obtained at TAS of ₦48,830,600, FCI of ₦37,422,000, TPC of ₦35, 053,000 and r of 5.4%.
- ✓ the investment payback time is 2.36 year for a fifteen years' investment plan.
- ✓ the risk associated with the predictions of the three profitability indicators show that the indicators are accurate with different influence of the economic parameters.

Given that the demand of LPG is on the increase and therefore, this LPG plant will be a long term investment with a good return.

Conflict of Interest

The authors declare that they have no conflict of interest.

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