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CNG-P: New Software for the Development and Performance Analysis of the Use of CNG Vehicles in Nigeria's Public Transportation System

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ABSTRACT: *Development and Performance Analysis of the use of CNG Vehicles as means of Public Transportation in Nigeria using CNG-P, a Newly Developed Software is presented in this work. Port Harcourt – Onitsha expressway is taken as case. This involves analysis on collection of gas from the sales point which is taken as a treatment plant about 10km off the route, through the pipelines to the sites of the CNG refueling stations which would be installed along the route to refill the vehicles. CNG-P was developed and used to conduct technical analysis of the project. From the analyses, the project is found to be very technically feasible. The technical parameters determined using CNG-P are: total gasoline gallon equivalent (GGE) requirement for the vehicles that would be plying the route; number of CNG refuelling stations to be installed along the route; the CNG refuelling station dispensing rate; desired flow rate of gas from the gas sales point to the pipeline and the stations; and the desired pressure at the inlet of the pipeline. The results got using CNG-P were compared with the results that were gotten from performing the analyses manually and the CNG-P results were found to correspond with the manual calculation results. This new software is a major contribution to knowledge as it would make it much easier for engineers and investors in the field of CNG vehicles usage to perform their analyses and take appropriate technical decisions.*

KEY WORDS: *compressed natural gas, technical analysis, pipeline, automobiles, refueling stations, CNG-P.*

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I. INTRODUCTION

Natural gas is found mainly in porous rocks (called reservoir) either associated with crude oil (called associated gas, AG), in gas reservoir with no crude (called non-associated gas, NAG) or coal bed (called coal-bed methane, CBM). In other words, natural gas is obtained from natural underground reservoirs either as free gas or as gas associated with crude oil (Anyadiegwu et al, 2014). Raw natural gases come from three types of wells namely oil wells, gas wells and condensate wells. Natural gas is considered " dry" when it is almost pure methane (C_1), most of the other commonly associated hydrocarbons having been removed but when other hydrocarbons are present, the natural gas is said to be "wet" (Anyadiegwu et al, 2014).

US Department of Energy, (2016) defined natural gas as an odourless, gaseous mixture of hydrocarbons - predominantly methane **(**CH_4**)**. It accounts for about a quarter of energy used in the United States. About one-third goes to residential and commercial uses, such as heating and cooking, one-third to industrial uses, and one-third to electric power production. US Department of Energy, (2016**)** studied natural gas under different uses: natural gas utilization in vehicles, renewable natural gas (RNG) also known as bio-methane, compressed natural gas (CNG) and liquefied natural gas (LNG). They stated that natural gas used in powering vehicles only about one-tenth is used for transportation fuel. They also found out that the majority of the natural gas in the US is fossil fuels because it is made from sources formed over millions of years by the action of heat and pressure on organic materials. Renewable natural gas is chemically identical to fossil-derived conventional natural gas and it can use the existing natural gas distribution system and must be compressed or liquefied for use in vehicles. Nwaoha and Iyoke, (2013) noted that CNG is often confused with LNG. While both are stored forms of natural gas, the key difference is that CNG is gas that is stored (as a gas) at high pressure, while LNG is in uncompressed liquid form at very low (cryogenic) temperature. CNG has a lower cost of production and storage compared to LNG as it does not require an expensive cooling process and cryogenic tanks. CNG is very cost-competitive when compared with other forms of natural gas, like LNG. Whenever LNG is more suitable for longer and larger vehicles, CNG is very attractive for smaller vehicle travelling shorter distance and for storing and developing small volume of gas. US Department of Energy, (2016) stated that CNG and LNG used as alternative transportation fuel are two forms of natural gas currently used in vehicles. They are both domestically produced with relatively low prices and commercially available.

1.1.8 Converting Gasoline/Diesel-powered Automobiles to use CNG

A converted vehicle or engine is one modified to use a different fuel or power source than the one for which it was originally designed, such as converting a diesel vehicle to run on propane, natural gas, or electricity.

Vehicles and engines can be converted to "dedicated" configurations, meaning they operate exclusively on one alternative fuel. They can also be converted to "bi-fuel" configurations that have two separate tanks - one for conventional fuel and another for an alternative fuel. Either fuel can be accessed by flipping a switch. The term dual-fuel typically refers to another type of configuration where two fuels are used for ignition. For example, a heavy-duty natural gas vehicle that uses a small amount of diesel for ignition assistance. Natural gas vehicle conversions provide alternative fuel options beyond what is available from original equipment manufacturers (OEMs). Qualified service retrofitters (QSRs) can economically and reliably convert many light- and medium-duty vehicles for natural gas operation. Natural gas engines and fueling systems are also available for some heavy-duty vehicles. This conversion involves installing extra parts into the diesel-powered vehicles that would make them bi-fuel powered vehicles. This means that they would be able to be both powered by diesel and CNG. The flow chart for the extra components and their connection sequence for the conversion of vehicles to CNG-powered are shown in Figure 1.1:

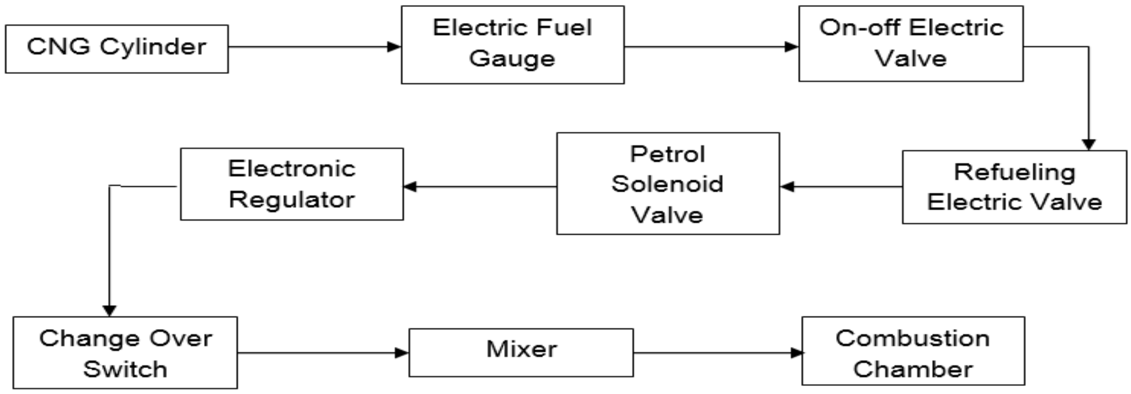

Fig 1.1: Flow Chart of the Installations for Converting Vehicles to CNG-powered

II. APPRAISAL OF NATURAL GAS UTILIZATION

2.1 Gas Utilization in Nigeria

Natural gas accounts for 12% of the total energy consumed in Nigeria (US Energy Information Administration, 2013). Out of estimated 5 bcf/day of gas productions, about 17% is re-injected, 33% is used for commercial purposes and the remaining 50% is flawed (Izuwa, 2017). This remaining unused gas can be converted to electricity, vehicular fuel and natural gas hydrate (Izuwa, 2015). Therefore, development and effective management of gas sector in Nigeria remains a strong channel for expansion and will generate opportunity for multiple revenues for Nigerian economy (Izuwa, 2017). Natural gas is a valuable fuel with increasing demand as the desire for clean and environmentally friendly fuel is required (Izuwa, 2015).

Natural gas liquid (NGL) is used in the industrial sector as a fuel for process heating as well as feedstock (or raw material) for the production of chemicals (such as NH_3, methanol-used in the manufacture of many polymers, butane, ethane, propane, hydrogen, and acetic acid). It is also an ingredient for the production of fertilizer, antifreeze, plastics, pharmaceuticals and fabrics. In the electric power sector, natural gas is used to generate electricity (US Energy Information Administration, 2016).

2.2 CNG as Alternative Fuel

Compressed natural gas (CNG) or methane stored at high pressure is a fuel which can be used in place of gasoline, diesel and propane/LPG. CNG combustion produces fewer undesirable gases than the fuels mentioned above.

Somsit, (1991) experimentally showed that a CNG engine consumes less energy (14 per cent less) than a gasoline engine. He also observed a remarkable decrease in air pollution when using CNG: 52 per cent for carbon dioxide (CO_2) and 13 per cent hydrocarbon content in the exhaust gas when compared to that of gasoline.

Munde and Dalu, (2012) reviewed CNG as an alternative fuel for SI engines and noted that many investigations carried out in order to use CNG as an alternative fuel in an engine could be divided into three (3) main types according to their fuel usage. Dual fuel is a development for conventional diesel engine where both diesel and natural gas are introduced into the engines cylinder during compression. Since natural gas will not ignite under compression alone, the diesel is required to ignite the gas/air mixture. When natural refuelling is not available, the engine can revert to conventional diesel operation. Bi-fuel is the type of engine based on the conventional gasoline engine where the fuel system has been modified to operate either CNG or gasoline. When CNG refuelling is not available, the engine is switched to normal running on gasoline. Dedicated or Single or Mono fuel is a specialized engine type, which has been designed and optimized to operate only on natural gas. This enables the characteristics of natural gas to be fully exploited without compromising in design to accommodate other fuels. They further noted that natural gas has been tested as an alternative fuel in a variety of engine configurations.

Chasos et al, (2014) worked on technical and feasibility analysis of gasoline and natural gas-fuelled vehicles. They examined the large-scale adaptation of natural gas as vehicle fuel in the economy of Cyprus Republic. In their research work carried out technical analysis of two types of internal combustion engine vehicles, namely gasoline and natural gas-fuelled vehicles. Their technical model uses the physical properties of the two fuels and the performance factors of internal combustion (IC) engines including brake thermal efficiency. The resulting gas emissions were also estimated by the technical model using combustion calculations which provided the expected levels of exhaust gas emissions. Based on the analysis with the technical model, comparisons of the two types of engines were performed. Furthermore, the estimated performance characteristics of the two types of engines, along with local statistical data on annual fuel imports and annual fuel consumption for transportation and data on the vehicles (fleet of cars) for the case study of Cyprus Republic were used as input data in the economic model. For the base year 2013, data of natural gas price was also used in the economic model. The model estimated the capital cost, the carbon dioxide emissions by avoidance of fines, the net present (NPV) and the internal rate of return (IRR) of the investment of large-scale adaptation of natural gas-fuelled vehicles for the case study. From the results and comparisons, natural gas vehicles can provide improved performance with reduced pollutant emissions.

As an alternative fuel for road vehicles, natural gas has a high octane rating (or octane number) and for pure methane the Research Octane Number (RON) is 30 (McCormick, 2016). This enables a dedicated engine to use a higher compression ratio to improve thermal efficiency by about 10% above that for a gasoline engine. CNG with lean burning quality leads to lowering exhaust emissions and fuel operating cost. CNG has a lower flame speed and the engine durability is very high (Munde and Dalu, 2012). Some properties of CNG compared to gasoline are as shown in Table 2.1:

Table 2.1: Thermodynamic Properties of CNG and Gasoline

Properties	CNG	Gasoline
Stoichiometric Ratio	15.7	14.2
Octane Number	120-130	96
Higher Heating Value	50.3	45
Lower Heating Value	45.9	42.2
Density @ 25^{o}C (kg/m^3)(DIN51757)	2.52	749
Molecular Weight (kg/kgmol)	16	106.2
Minimum Ignition Energy (MJ)	0.26	0.33
Laminar Flame Speed (cm/sec)	37.5	30
Flammability Limits (vol% in air)	15.6	5.2
Adiabatic Flame Temperature (k)	2266	2227

Source: Munde and Dalu (2012).

The result indicated that a retrofitted CNG engine produces about 16% less brake mean effective pressure (BMEP) and Consumes 17-18% less brake specific fuel consumption (BSFC). This translates to an average of 1.65mj less energy per kilowatt hour (kWH) at wide open throttle (WOT) condition with CNG compared to gasoline. On the average, the retrofitted engine reduces CO by about 80%, CO_2 by 20% and HC by 50%. Similar experimental investigation conducted by Jahiral et al, (2010) with a retrofitted car engine using a 1.6l, 4-cyclinder gasoline engine compared performance and emissions analysis of CNG and gasoline. They measured engine performance and exhaust emission over a range of speed variation at 50% and 80% throttle proportion. The result respectively showed 19.25% and 10.86% reduction in brake power (BP) and 15.96% and 14.68% reduction in BSFC while the engine was fuelled with CNG compared to that with gasoline emission like un-burnt HC, CO and CO_2 were significantly lower for CNG than those of gasoline.

2.3 Environmental Benefits of CNG Fuel

CNG fuel has attracted considerable interest due to its low air pollutants emission, low cost and availability (Lozano-Castello et al, 2002; Liang et al, 2012; and Khan and Yasmin, 2014) when compared with gasoline and other liquid-fuelled vehicles, natural gas vehicles (NGVs) produce 87 per cent less nitrogen oxides, 89 per cent less non-methane organic gas and 70 per cent less carbon monoxide (Liang et al, 2012). Therefore natural gas is more environmentally friendly than liquid fuels like gasoline and diesel (Khamforoush et al, 2014).

2.4 Current Status of CNG Development In Nigeria

Igweonu and Mbabuike (2011) made a case for utilization of Compressed Natural Gas (CNG) for automobiles in Nigeria. They argued that the issues that make it important are safety, affordability (fuel pricing), environmental and regulatory requirements as well as distribution network. They found out that at present, CNG provides fuel for more than eleven million natural gas vehicles (NGVs) on the road globally, with Pakistan (often referred to as a 'gas-based economy') alone accounting for about 2.2 million. Oando is the developer of Nigeria's foremost natural gas distribution network. In 1999, Unipetrol acquired 40 per cent equity of Gas-link to utilize its exclusive gas sale and purchase agreement with the Nigeria Gas company (NGC). They delivered the first gas to Cadbury Nigeria Plc at Ikeja, Lagos, in 2000. The Gaslink Ikeja 1A pipeline expansion project was completed in 2001; and Ikeja 1B pipeline expansion project was completed in 2002. In 2004 Gaslink's Greater Lagos (GL) II Pipeline-expansion project was completed. Gaius-Obaseki (2001) reviewed the evolution of the use of CNG in Nigeria and stated that the Nigerian Gas Company (NGC) has been in the vanguard for the development of CNG vehicles in Nigeria. It elevated the profile of natural gas to a level of considerable relevance in the local Nigerian energy mix, including venturing into frontier areas of compression of natural gas and its utilization. NGC had at a time embarked on a pilot scheme with a view to ascertaining the technical and commercial viability as an automotive fuel and an alternative to gasoline. It embarked upon the CNG scheme in 1989 on a pilot basis to promote CNG as an automotive fuel. It installed a CNG conversion workshop with cylinder test rig in its Warri office.

2.5 CNG Refuelling Stations

According to Wilson Technologies Incorporated, (1997), refuelling stations are critical for development and diffusion of CNG as transportation fuel for automobiles. Thus lack of CNG station is one of the crucial impediments to wider market implementation of CNG vehicles. A CNG station is built for either retailing use or for fleet application. Its design requires calculating the right combination of pressure and storage needed for the types of vehicles being fuelled. The right choices about the size of compressor and the amount of storage at the station impact the cost of fuel and range for vehicles. Figure 2.1 is a photographic illustration of a typical CNG fuelling station.

Fig 2.1: Photograph of a typical Public CNG Fuelling Station (Source: TruStar Energy, 2018).

CNG utilizes reticulated natural gas that is delivered to the CNG station by a network of underground pipelines – the same pipelines that deliver natural gas to residential, commercial and industrial premises. The natural gas is compressed on site and, if necessary, small quantities of CNG are stored in cascade storage cylinders on site to enable high flow dispensing to the vehicle. In some cases, the cascade storage is omitted and the CNG is dispensed directly into the vehicle cylinders at a much slower flow (United States Department of Energy, 2017).

III. METHODOLOGY

3.1 Development of Natural Gas as Transportation Fuel

Natural gas is transformed to automotive transportation fuel using compression equipment. The procedure employed in the development of natural gas as transportation fuel comprises:

1. Determination of the gasoline gallon equivalent (GGE) requirement of the CNG vehicles to enable the quantity of CNG utilization to be known.
2. Design of pipeline network and refueling stations to be installed.
3. Laying of natural gas pipelines from gas supply (gas gathering) plants from the oil and gas fields to the sites where the CNG refuelling stations would be sited.

The route used as case for the project is Port Harcourt to Onitsha Expressway. CNG refuelling stations would have to be installed along the expressway while gas pipelines are laid across to transport gas to the CNG refuelling stations where it would be compressed and stored for refuelling the CNG vehicles that would ply the route.

3.2 Estimation of Total GGE per Day

After some surveys of vehicles and passengers along the Port Harcourt - Owerri - Onitsha route, the estimate of the number of individuals that leave Port Harcourt to Owerri and then to Onitsha is taken as 5500. Most of the commercial vehicles that ply the route are 14-seater buses. This implies that the average vehicle-passenger capacity is 14 passengers. The number of vehicles that ply the Port Harcourt - Onitsha route to and fro is estimated; and this estimate enables us to determine the total GGE requirement for the day. This is achieved by taking an estimate of the number of individual commuters from Port Harcourt to Onitsha and from Onitsha to Port Harcourt daily, and analyzing this with the average passenger capacity of the vehicles.

The number of similar vehicle models plying the route from Port Harcourt - Onitsha daily can be estimated as follows:

$$\mathbf{N_V = N_{PT}/ VP_C} \qquad \mathbf{3.1}$$

Where,

N_{PT} = Total number of passengers (commuters),

VP_C = Vehicle passenger capacity.

The fuel tank of the light duty CNG vehicle used for this analysis holds 8.0 gasoline gallon equivalent (GGE) of CNG at 3600psi, and can cover an average of 200 miles (322km) with a full CNG tank; which translates to 0.0248 GGE per km. According to Igweonu and Mbabuike (2011), one GGE equals 0.77Scf of CNG at 3600psi and 126Scf of natural gas at standard temperature and pressure.

The daily total volume of CNG required for plying the route is determined by first determining the GGE requirement for plying the route to and fro per day for light duty or heavy duty vehicles. The specific GGE requirement over a given distance for the type of vehicle used for the analysis is used to make this estimate.

The GGE requirement for light-duty vehicles (L_{GGE}) is estimated as:

$$\mathbf{L_{GGE} = L_{GGEk} * N_V * 2\, L_p} \qquad \mathbf{3.2}$$

Where,

L_{GGEk} = GGE requirement for light duty vehicle per km,

L_p = Distance from Port Harcourt to Onitsha.

Since one GGE equals 0.77Scf of CNG at 3600psi, the CNG requirement in scf is estimated as:

$$\mathbf{CNG_{LVol} = L_{GGE} * 0.77} \qquad \mathbf{3.2a}$$

The GGE requirement for heavy duty vehicles (H_{GGE}) is also determined as:

$$\mathbf{H_{GGE} = H_{GGEk} * N_V * 2L_p} \qquad \mathbf{3.3}$$

Where,

H_{GGEk} = GGE requirement for heavy duty vehicle per km.

The CNG requirement in scf is estimated as:

$$\mathbf{CNG_{HVol} = H_{GGE} * 0.77} \qquad \mathbf{3.3a}$$

3.3 Design of Pipeline Network and CNG Stations

According to Ikoku, (1992), there are varying factors that affect the design of a gas transmission network. Some of these factors include:

- Optimum pipeline diameter
- Compressor horsepower
- Nature and volume of gas to be transported
- Transmission area
- Length of the line
- Type of terrain to be crossed
- Maximum elevation of the route
- Location of the treatment plant where the gas is got
- Gas inlet and outlet pressures
- Pipeline specification - relative roughness, yield strength.

3.3.1 Pipeline Network

The gas used as CNG is got from a gas treatment plant owned by one of the gas producers in the Niger Delta region of Nigeria. This particular gas processing plant is chosen because of its closeness to the route. The plant is 10km (6.21miles) from Port Harcourt. Figure 3.1 shows the gas processing/gathering plants in the Niger Delta region of Nigeria. Before transportation, the gas is compressed to the required pipeline inlet pressure, P_1 by the user.

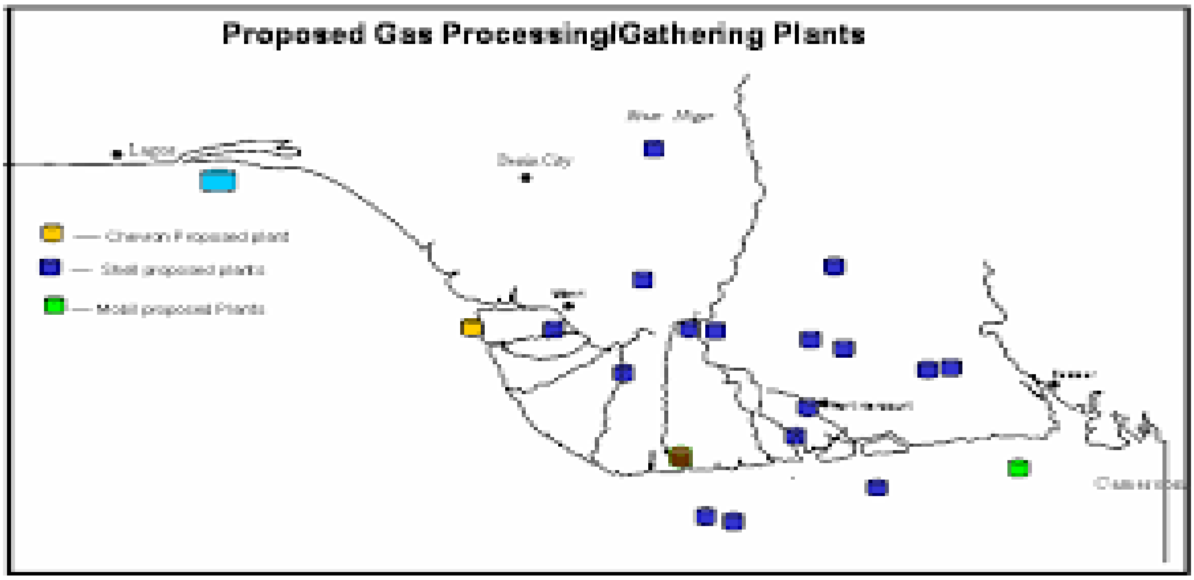

Figure 3.1: Gas processing/gathering plants in the Niger Delta region of Nigeria (Yar'Adua, 2007).

3.3.2 Pipeline Arrangement for Gas Transportation

Pipeline would be laid from the gas processing plant to the sites of the CNG refuelling stations. The distance between the treatment plant and the route, added to the distance from Port Harcourt - Onitsha, would bring the total distance to 126.68 miles. The average temperature of the gas in the pipeline is 179.9^{0}F. The hourly flow rate of the gas is the total volume of gas per hour needed by the CNG stations for the CNG vehicles. This is expressed as:

$$Q = CNG_{LVol} * 126 / (0.77 * 24) \qquad \textbf{3.3b}$$

This flow rate is expressed in scf/hr as shown in the pipeline dimensions and gas properties represented in Table 3.1 below.

Table 3.1: Pipeline and Gas Parameters for Transportation

Flow rate, Scf/hr	20239
Base pressure, psia	14.7
Base temperature, ^{0}R	520
Gas specific gravity	0.69

Gas Z-factor	0.92
Average temperature, ^0R	639.9
Pipeline length to station, miles	126.68
Diameter of pipeline, in	12
Min Station inlet gas pressure	30psia

Weymouth equation was used in this work for the estimation of pipeline inlet pressure and selection of pipe dimensions.

The single pipeline arrangement which is adopted in this work is the most conventional pipeline arrangement because it makes use of only one straight pipe of same diameter from the beginning to the end. It is also the cheapest pipeline arrangement. A schematic of single pipeline arrangement is as shown in Figure 3.2 below.

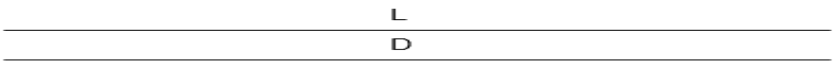

Fig 3.2: Schematic of Single Pipeline Arrangement

The initial pressure, P_1 is estimated using Weymouth equation for single pipeline arrangement as (Guo et al, 2005):

$$\mathbf{P_1 = [(Q * P_b/18.062T_b)^2 * SG * Z * T_{avg} * L/D^{16/3} + P_2^2]^{0.5}} \qquad \textbf{3.4}$$

Where Q = flow rate, scf/hr

P_b = base pressure, psia

T_b = base temperature, ^0R

SG = gas specific gravity

Z = gas compressibility factor

T_{avg} = gas average temperature, ^0R

L = pipe length, miles

D = pipe diameter, inch

P_2 = pipeline outlet pressure or minimum station inlet gas pressure, psia

The number of pipe segments (N_{ps}) to be laid to cover the entire distance is estimated as:

$$\mathbf{N_{ps} = L / L_{avg}} \qquad \textbf{3.5}$$

Where L_{avg} = length per pipe segment, miles.

The number of pipes (N_p) to be laid to cover the entire distance is estimated as:

$$\mathbf{N_p = 5280 * L / L_p} \qquad \textbf{3.5a}$$

Where Lp = length per pipe, ft

3.3.3 Number of Refueling Stations

The number of CNG refueling stations (N_{CS}) to be installed is determined as:

$$\mathbf{N_{CS} = L_{GGE} / R_{max}} \qquad \textbf{3.6}$$

Where R_{max} = maximum dispensing rate of CNG refueling station

3.4 Development of CNG-P Software for the Technical Evaluation

Microsoft Excel - Visual Basic program (Excel-VBA) was used for the development of software for the technical evaluation of compressed natural gas as an alternative fuel for automobiles in Nigeria. The name of the **software is CNG-P**. The technical analysis is conducted using the developed Microsoft-Excel Visual Basic program. A sample of the input interface for the program is as shown in Figure 3.3 below.

Fig 3.3: Input Interface of CNG-P

IV. PRESENTATION OF RESULTS

4.1 Application of CNG-P for the Analysis of the CNG Automobile Transportation Project

The newly developed software, CNG-P was used to perform the technical analysis of the use of CNG vehicles for transportation in Nigeria. This was done by feeding the required data into CNG-P for the evaluation of the required parameters. The input interface of this analysis is as shown in Figure 4.1.

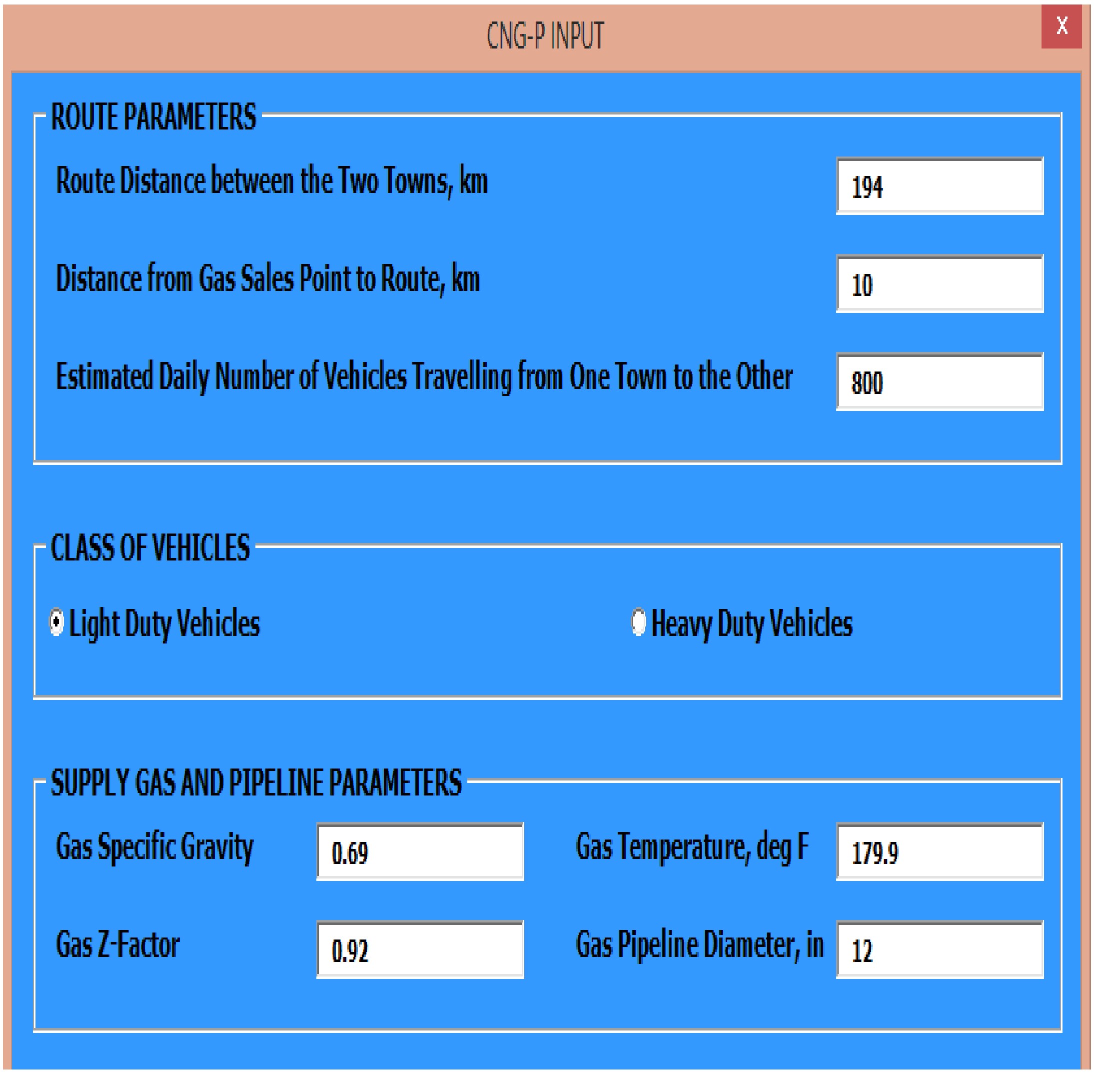

Fig 4.1: Input for the Technical Analysis of the Project using CNG-P

The results of the technical analysis are shown in Table 4.1.

Table 4.1: Results of the Technical Analysis using CNG-P

TECHNICAL PARAMETERS	VALUES
Gasoline Gallon Equivalent (GGE) Requirement per Vehicle, GGE	4.82
Total Vehicles Gasoline Gallon Equivalent (GGE) Requirement, GGE	3855.18
Number of CNG Stations to be Installed along the Route	5
CNG Refuelling Station Dispensing Rate, GGE/day	800.00
Desired Flow Rate of Gas from the Gas Sales Point to the Pipeline, scf/hr	20239.71
Desired Pressure at the beginning of the Pipeline, psia	31.47
Inlet Pressure of Gas at the CNG Refuelling Stations, psia	30.00

4.2 Comparison of the CNG-P Results with Manual Calculation Results

Performing the analyses manually would yield the results shown together with the CNG-P results in Table 4.2.

Table 4.2: Results of the Analyses using CNG-P and Manual Calculation

TECHNICAL PARAMETERS	CNG-P Results	Manual Calc Results
Gasoline Gallon Equivalent (GGE) Requirement per Vehicle, GGE	4.82	4.82
Total Vehicles Gasoline Gallon Equivalent (GGE) Requirement, GGE	3855.18	3856.00
Number of CNG Stations to be Installed along the Route	5	5
CNG Refuelling Station Dispensing Rate, GGE/day	800.00	800.00
Desired Flow Rate of Gas from the Gas Sales Point to the Pipeline, scf/hr	20239.71	20239.00
Desired Pressure at the beginning of the Pipeline, psia	31.47	31.47
Inlet Pressure of Gas at the CNG Refuelling Stations, psia	30.00	30.00

V. CONCLUSIONS

Development and Performance Analysis of the use of CNG Vehicles as means of Public Transportation in Nigeria using CNG-P, a Newly Developed Software was conducted in this work. From the analyses conducted, the following conclusions can be drawn:

- The use of CNG vehicles as a means of public transportation is technically feasible.
- CNG-P is a very reliable software for technical analysis of the CNG project as the results corresponded with the manual calculation results.
- This new software would make it much easier for engineers and investors in the field of CNG vehicles usage to perform their analyses and take appropriate technical decisions.

RECOMMENDATION

Having conducted the technical analysis of the introduction of CNG vehicles as means of public transportation using the newly developed software, CNG-P, an area that is recommended for further work on is the economic analysis of the introduction of CNG vehicles as means of public transportation using the newly developed software CNG-P, based on the evaluations done in this work.

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