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Use of Analytical Hierachy Process (AHP) To Compare Transportation Modes of Gas-To-Liquid (GTL) Products from the Niger Delta Region of Nigeria to Overseas

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***Abstract*— In the selection of transportation mode, decision makers are confronted with a lot of criteria; such as availability, delivery time or speed, price, reliability and safety. Under these criteria, two transportation modes are considered in this study. They include pipeline and marine for GTL products from the Niger Delta region of Nigeria to US or Europe. AHP is a very useful tool in this respect. It applies statistics and modelling to decision selection. Based on the model, marine transportation mode result was calculated to be 0.590 while pipeline was calculated to be 0.410. Hence marine transportation mode becomes the preferred option.**

***Index Terms*— Transportation mode, Gas-to-Liquid, pipeline, marine, products. availability, speed, price, reliability and safety..**

I. INTRODUCTION

Transportation is the most important component of logistics. GTL products need to be sold in US or Europe from Escravos in the Niger Delta region of Nigeria due to high premium placed on the quality of the products. Appropriate transportation mode is therefore necessary in minimizing cost. In this study, marine and pipeline transportation modes according to their criteria were examined for GTL products. A matrix representation of the model was obtained. Analytical Hierarchy Process (AHP) based model was employed in analyses to get the best transportation mode.

II. LITERATURE REVIEW

AGTL PRODUCTS PIPELINE TRANSPORTATION MODE.GTL products are similar to refined petroleum products and so can be transported using existing infrastructure. Ways on the mode of transporting GTL products in Trans Alaska pipeline systems were carried out successfully (Chukwu, 2002). They include the slug/batch mode and the co-mingled/ mixed mode.

B THE SLUG/BATCH MODE

This refers to the alternate transportation of batches of crude oil and GTL products along the line. An interface zone between the two phases is created. The length of this interface is a function of viscosity, velocity, density difference between the two products, pipeline diameter and distance.

C THE CO-MINGLE/ MIXED MODE This mode involves mixing of crude oil and GTL products and transporting the mixture. This blending process leads to extreme contamination of the GTL fuel by sulphur, waxes and other impurities. It increases reprocessing cost for separating the mixture. The reprocessing process includes;1 Distillation: to remove both sulphur and colour bodies from contaminated GTL products. Distillation is the only process being used to separate interface material into original components. It is complex and has high operating cost.**2**Metal-Oxide Treatment: It is used to remove sulphur from contaminated GTL products.3Caustic Treatment: It is also used to remove sulphur only from contaminated GTL products. It has high operating cost, complex and pose challenges for the disposal of used caustic.

Transportation modes of GTL products include pipeline and maritime transportation.

D PIPELINE TRANSPORTATION OF LIQUID PETROLEUM PRODUCTS

Pipeline transportation of liquid products is better for shorter hauls and thus should dominate local and regional trade. Within local and regional trade, pipeline transportation is cheap, less hazardous and more environmentally friendly. Pipelines accrue the costliest fixed cost and smallest variable cost among other transportation modes. High fixed costs emanate from the right of way of pipeline construction and the necessity to have control stations, and pumping capacity. Subsea pipeline construction is both economically and technically challenging. Most liquid products at sea is transported by tank ships. All international trade of Crude oil and petroleum product that involve long distance and trans-oceanic carriage is done by ship despite the fact that tank ships may run empty during return trips (Pienaar, 2009)

E CONSTRAINTS ON THE PIPELINE SYSTEM SUBSEA TRANSPORTATION

Potency of soil and stability of the sea floor with other environmental conditions such as water depth, temperatures, marine life and other activities in the area such as shipping and industrial operations affect laying of pipelines. Safety and reliability of the pipeline system must be guaranteed. Laying of pipeline in arctic conditions require thorough survey. This means looking for ice gouges and strudel scours. Ice gouging can occur when ice keels contact the sea floor. The gouges indicate where pipeline must be buried to protect them from the Ice keels. Strudel scours are formed during the spring melt, when fresh water from local stream and river break ups flow over the sea ice. This water finds seal breathing holes or

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cracks in the ice pipeline (www. shell.us/alaska).

F MARITIME TRANSPORTATION MODE

Considering the fact that EGTL plant is located in the offshore region of the Niger Delta and the quantity of GTL products for marketing overseas require high capacity carrying tanker for transportation over long distances, marine transportation becomes the most suitable. Ships operate mostly in international trades. They carry mostly liquids and dry bulk cargo and often non mixable products in separate compartments. Ships are made in different sizes. Ship sizes are rated by its weight carrying capacity and the volume capacity of the products being transported. Dead weight (DWT) is the weight carrying capacity of a ship, in metric tons. Tankers are designed to carrying liquids in bulk. Gross Tons (GT) is the volume of the enclosed spaces of the ship in hundreds of cubic feet. Hauling capacity of a ship is the product of ship size and its speed, while handling capacity of a ship is the cargo loaded or unloaded per unit time (Christiansen et al.; 2007). All tankers must have modern communication systems, which rely on satellites for communication in case of emergency. Since 1990, US and international regulations require all new ships to be double-hulled. The cargo is carried within an inner hull, which is protected by a second outer hull. The space between the hulls varies by ship size from seven to ten feet or more. Table 2.1 shows the tanker categories and carrying capacities. .Any empty space is filled with inert gas to eliminate the risk of combustion. The inert atmosphere keeps the tanks free of oxygen, which must be present for combustion to occur. In the event of fire, fire system pumps sea water to sprinklers to put off the fire. (shell in offshore Alaska www.shell.us/alaska).

Table 2.1: TANKER CATEGORIES AND CARRYING CAPACITIES.

Tanker	Length (ft)	Capacity (bbl)
Panamax	760	500,000
Aframax	800	800,000
Suezmax	900	1,000,000
VLCC	1000	2,000,000
ULCC	1300	3,000,000

Source: (www.shell.us/alaska).

However, there are some challenges in marine transportation which include the following:

(a) Higher uncertainty in their operation due to their higher dependence on weather conditions and on technology,

(b) Floods or periods of low water may limit when or where they can operate,

(c) Slow speed about 28km/hr,

(d) Delays encountered in Ports during loading and offloading especially where rapid deliveries are required (Rodrigue et al., 2013).

Recent technological advancement that have affected water transport has shown more emphasis on improving water channels and also improving water channels and also improving the size, automation and specialization of vessels and constructing port terminals as prerequisite for marine transportation (Rodrigue et al., 2013).

The lower cost of moving GTL products in liquid tankers, relative to more expensive trans ocean pipeline over long distances makes liquid tankers more competitive. In this study, shipment by tankers is recommended as can be seen in the study conducted by(Horner ,1986).

Horner (1986) conducted a study to ascertain the cost per mile for movement of petroleum products via pipeline and water carriers and came up with the following as shown in Table 2.2. For 500 mile haul, the estimated rates are

Table 2.2: COST PER MILE FOR DIFFERENT TRANSPORTATION MODES.

Transportation mode	Cents/500 bbl. Miles	Average C/100 bbl mile	Mills/Ton mile
Pipeline	16-50	5.4	4.0
Tanker	12-15	2.7	2.0
Barge	14-18	3.3	2.5

If each of the foregoing transportation facilities is used over a distance for which it is reasonably well suited, the rate may be compared as follows in Table 2.3

Table 2.3: COST FOR DIFFERENT TRANSPORTATION MODES WITH DISTANCE.

Transportation mode	Distance Miles	Average C/100 bbl mile	Mills/Ton mile
Pipeline	1000	3.7	2.8
Tanker	2,200	1.6	1.3
Barge	500	3.3	2.5

It is seen from the foregoing that the cost per mile for movement via pipeline and water carriers are comparatively close. In-practice, the selection of facilities used must consider among others, factors such as the comparative length of water and pipeline routes, the availability of navigable water, terminal cost, winter icing problems (Horner, 1986).

G MARINE TRANSPORTATION OF LPG

LPG is mainly transported using specific transportation vessels. Pressurized, semi pressurized or refrigerated vessels are used for that purpose. The pressurized (18 bar, ambient temperatures) LPG ships carry 3-10,000 m^3 while refrigerated LPG ships (5-8 bars and -10^oC to -20^oC) carry 10-30,000m^3 respectively. Fully refrigerated vessels have cargo volumes ranging from 35,000m^3 to 100000m^3 (Porttechnology.org).The offshore terminal consist of a mooring and fluid transfer system (SPM), connected by means of a subsea pipeline to the LPG Storage facility onshore. The SPM mooring system enables the vessel to freely weather vane in response to wind vane and current conditions. Insulated pipelines are basically required in the transfer of LPG from the storage tank through the fluid transfer system to keep the LPG from heating due to environmental effect. This insulation keeps the product at the agreed temperature between the terminal operator and the shipping company (Porttechnology.org)

H EFFECTS OF CRUDE PROPERTIES ON FLUID TRANSPORTATION.

1 VAPOUR PRESSURE

The vapour pressure of the liquid is the pressure exerted on the liquid by its own vapour at a particular temperature. The

liquid will boil when the net positive suction head is equal or less than the liquid's vapour pressure developing bubbles that may eventually collapse on the pump impeller resulting to cavitation. Vapour pressure determines the liquid emission rate and volatility. When liquid is below its vapour pressure solid, deposition takes place.The pipeline pressure must at all time be greater than the liquid vapour pressure to prevent foaming and cavitation of the centrifugal pump.

Reid vapour pressure is measured at 100^0F and results obtained are later on converted to True vapour pressure, using equation 2.6

$TVP_{corrected} = TVP_{calc} + C_F$(2.1)

Where the correction factor,C_F is given as follows in equations 2.2 and 2.3

If RVP < 3, then $C_F = 0.04 \times RVP + 0.1$(2.2)

If RVP >3, Then C_F = Exp (2.3452061 x log (RVP) – 4.132622)

TVP = RVP x Exp (A) (2.3)

Where A is given by equation 2.9

$A = C_o$ (IRTEMP-ITEMP). (2.4)

C_o is a proportionality constant (negative value), the value of which depends on the value of RVP

ITEMP = $(555.69^0R)^{-1}$

IRTEMP = $(T_s+459.69^0R)^{-1}$

T_s = the fluid temperature (^{0}F)

2 SATURATION PRESSURE

If the bubble point or saturation pressure of the GTL products is less than the pipeline condition, it would exist as a single phase liquid at pipeline condition.

3 GEL STRENGTH.

As the temperature drops, the gel strength increases which consequently result in an increased viscosity. On the other hand in a tropical environment, the gel strength decreases, resulting in decreased viscosity and increase in flow rate. Crude oil moves at a speed of (3-8) miles per hour via pipeline. Pipeline transport speed depends on some number of factors which include diameter of pipe, pressure at which the oil is being transported, topography of the terrain and viscosity of the oil being transported.

4 DENSITY AND VISCOSITY MEASUREMENT

The pressure requirement for an optimum pipeline system is affected by the fluid's density and viscosity which also characterizes the conditions for flow through the pipeline for that same fluid. As the temperature increases, density of gtl products decreases, and viscosity also decreases. Chukwu et al. (2007) conducted a study at various temperatures through TAPS using different GTL brands and observed that the pressure drop increases as temperature decreases. Crude oil at temperatures 20^{o}C and above exhibit Newtonian behaviour but below 20^{o}C exhibit Bingham flow behaviour (Chukwu et al., 2007). This is shown in Table 2.4 below.

5 RHEOLOGY EFFECTS ON FLUID TRANSPORTATION

The concepts of shear stress and shear rate apply to all fluid. Shear rate depends on the average velocity of the fluid in the geometry in which it is flowing. They are higher in smaller geometries and smaller in larger geometries. Higher shear rates cause a greater resistive force of shear stress. Shear stress is the force in the flowing fluid which opposes flow.

H SELECTION OF TRANSPORTATION MODE USING ANALYTICAL HIERARCHY PROCESS (AHP) BASED MODEL

In this study the preferred transportation mode will be selected from the two different modes. The modes include pipeline and marine. Decision Support System (DSS) was developed using Analytical Hierarchy Process (AHP) based model (Saaty,1980). The model will be used to determine availability, speed, price, reliability and safety criteria that affect the two transportation modes as shown in Fig.2.1 below.

Analytical hierarchy process selects the best among a set of criteria to be evaluated and a set of alternative scenarios. It produces a weight for each evaluation criterion. Scale of evaluation is shown in Table 2.5 below

Table 2.5 Pairwise comparison scale for AHP preference (Al-Harbi, 2001)

Numerical rating ofpreference	**Verbal judgments**
9	Extremelypreferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 2.6 Average random consistency (Al-Harbi, 2001)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The criteria which are considered in this work are as follows:

(a) Cost. The cost criterion is important in the selection of transportation mode

(b) Speed. Speed is usually referred to as the distance covered over a period of time. The time it takes to move the products from one point to another point.

(c) Safety. This criterion evaluates the risk of being damaged and loss of products during transportation period.

(d) Reliability. This is the ability of the transport system to eliminate the unforeseen circumstances that can lead to delays of transported goods from one point to another.

(e) Availability. Availability should be assessed in terms of transport from house to house. It largely depends on the level and extent of the infrastructure of the transport system.

III. METHODOLOGY

A DECISION SUPPORT SYSTEM USING ANALYTICAL HIERARCHY PROCESS (AHP).

In order for AHP to make reliable and reasonable decision, a model is built with the primary aim of selection criteria which depends on the choices made.This selection is done by pair wise comparison. A scale 1-9 grades is used for choices comparison in the model. After carrying out a good comparison with respect to goal and choices of criteria, arepresentation of the model is done on matrix. The choice is then calculated with the help of linear algebra transformation of the decision matrixEvaluation matrix of each criterion was performed using excel work sheet in each case scenario as shown in table 4.1 – 4.3 and consistency ratio values fall within the range of 0 and 0.1 signifying acceptance of decision criteria in all cases. Eigen value is calculated using 5 x 5 and 5 x 1 matrix multiplication as shown below. Results generally indicate that marine transportation mode has higher priority value than pipeline. Scale of evaluation is used to compare choices in the model.Each matrix element is normalized by the sum of elements in each column and the sum for each row is also calculated as in shown in Tables 4.1 – 4.3 using excel work sheet.

TABLE 2.4: FLOW BEHAVIOUR OF CRUDE OIL, ITS VISCOSITY AND YIELD POINT AT DIFFERENT TEMPERATURES (Chukwu et al.,2007).

Fluid	Temperature		Flow Behavior	Abs Viscosity/PV	YP
	^{O}C	^{O}F		Centipoise	$N.s^{n}/m^{2}$
Crude oil	50	123	Newtonian	7.99	
	45	113	Newtonian	8.97	
	40	104	Newtonian	10.06	
	35	95	Newtonian	11.39	
	30	86	Newtonian	13.27	
	25	77	Newtonian	15.12	
	20	68	Newtonian	18.35	
	15	59	Bingham	25.54	0.3991
	10	50	Bingham	34.61	0.9555
	5	41	Bingham	56.21	1.3611
	0	32	Bingham	109.84	1.9066
	-5	23	Bingham	318.16	2.2934

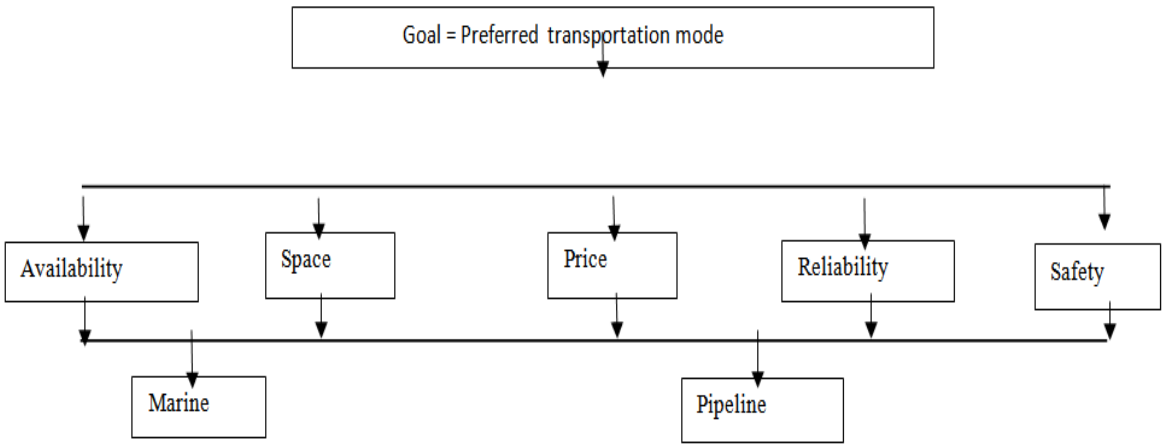


Fig 2.1: Analytical Hierarchy Process model application

B Base Case Calculation for Determination of Eigen Value

Step 1

1.0	5.0	4.0	5.0	4.0
0.2	1.0	2.0	1.0	3.0
0.25	0.5	1.0	2.0	1.0
0.20	1.0	0.5	1.0	3.0
0.25	0.33	1.0	0.33	1.0

Step 2 Weighted row average

0.53	0.64	0.47	0.54	0.33		0.502
0.11	0.13	0.24	0.110.25		0.168	
0.13 0.06		0.12	0.21	0.08	=	0.120
0.11	0.13	0.06	0.11	0.25		0.132
0.13	0.04	0.12	0.04	0.08		0.082

Calculation of Eigen Value using Multiplication of 5 x 5 and 5 x 1 Matrix

Step 3

1.0	5.0	4.0	5.0	4.0		0.502
0.2	1.0	2.00	1.0	3.0		0.168
0.25	0.5	1.00	2.0	1.0	x 0.120	
0.20	1.0	0.5	1.0	3.0		0.132
0.25	0.33	1.0	0.33	1.0		0.082

0.502 + 0.84 + 0.48 + 0.66 + 0.238 = 2.810
0.1004 + 0.168 + 0.24 + 0.132 + 0.246 = 0.888
0.1255 + 0.084 + 0.24 + 0.132 + 0.246 = 0.676
0.1004 + 0.168 + 0.06 + 0.132 + 0.246 = 0.706
0.1255 + 0.0554 + 0.120 + 0.0436 + 0.82 = 0.4265
Divide the product after multiplication of 5 x 5 and 5 x 1 for each row by the weighted average of each row in step 2
2.81/0.502 = 5.598
0.888/0.168 = 5.2865
0.676/0.120 = 5.633
0.706/132 = 5.348
0.4265/0.082 = 5.201
Total = 27.066
Sum average $\frac{27.066}{5} = 5.413 = \lambda max$
Consistency lndex (CI) is calculated using equation 3.1
Consistency Index = λmax - n / n-1 (3.1)

$$Cl = \frac{\lambda max}{n-1} = \frac{5.413-5}{4} = \frac{0.413}{4} = 0.1$$

Consistency ratio (CR) is calculated using equation 3.2
(CR) = Consistency index (CI) / Random consistency (RC) (3.2)

$$CR = \frac{0.1}{1.12} = 0.09$$

C Priority Availability Matrix Calculation for Determination of Eigen value

1.0	9.0	9.0	9.0	9.0		0.69
0.11	1.0	1.0	1.0	1.0		0.07
0.11	1.0	1.0	1.0	1.0	x 0.07	
0.11	1.0	1.0	1.0	1.0		0.07
0.11	1.0	1.0	1.0	1.0		0.07

Divide the product after multiplication of 5 x 5 and 5 x 1 for each row by the weighted average of each row.

0.345/0.690 =3.45
0.356/0.07 =5.08
0.356/0.07 =5.08
0.356/0.07 =5.08
0.356/0.07 =5.08

Total=25.32 Average of the five values = $\frac{25.32}{5} = 5.06$

$\therefore \lambda max = 5.06$

$\therefore$ Consistency Index (CI) = $\frac{\lambda max - n}{(n-1)} = \frac{5.06-5}{4} = 0.015$

CR = $\frac{CI}{RC} = \frac{0.015}{1.12} = 0.01$

D Priority Speed Matrix Calculation forDetermination of Eigen Value

0.07+ 007+0.07+0.07+0.07 = 0.35
0.64 +0.69+0.63+0.63+0.63 = 3.22
0.07+0.07+0.07+0.007+007 = 0.35
0.07+0.07+0.07+0.07+0.07 = 0.35
0.07+0.07+ 0.07+0.07+0.07 = 0.35

Divide the product after multiplication of 5 x 5 and 5 x 1 for each row by the weighted average of each row.

$\frac{0.35}{0.07} = 5.0, \frac{3.22}{0.69} = 4.7, \frac{0.35}{0.07} = 5, \frac{0.35}{0.07} = 5, \frac{0.35}{0.07} = 5.0$

Total = 24.7

$\therefore$ Average of the five values = $\frac{24.7}{5} = 5$

$\therefore \lambda max = 5.00$

$\therefore$ Consistency Index (CI) = $\frac{\lambda max - n}{n-1} = \frac{5.00-5}{4} = 0$

Consistency Ratio CR = $\frac{CI}{RC} = \frac{0}{1.12} = 0$

Consistency ratio for price, reliability and safety can also be calculated in a similar manner.

If CR value $\leq$ 0.1, Decision criteria is acceptable but if CR value > 0.1, Decision criteria is not acceptable.

IVRESULTS AND DISCUSSIONS. Computed results are shown in chapter 4, Tables 4.1 – 4.3below using excel work sheet. Evaluation matrix of each criterion was performed using excel work sheet in each case scenario as shown in table 4.1 – 4.3 and consistency ratio values fall within the range of 0 and 0.1 signifying acceptance of decision criteria in all cases. Eigen values were calculated using 5 x 5 and 5 x 1 matrix multiplication as shown in chapter 3. The outcome of the study has demonstrated that marine transportation mode has higher priority value than pipeline in each case scenario. In base case, marine priority value is 0.590 while pipeline is 0.410. When availability criterion is considered strongly important on evaluation scale of 9.0 with respect to other criteria, marine priority value is 0.620 while pipeline is 0.380. Considering speed criterion on evaluation scale of 9.0 with respect to other criteria, marine priority value is 0.579 while pipeline is 0.421. In the same way priority values can be calculated for marine and pipeline in respect of price, reliability and safety .

TABLE 4.1: ANALYTICAL HIERARCHY PROCESS MODEL OF PIPELINE AND MARINE TRANSPORTATION MODE.

Decision support system for selecting the best Transportation Mode using Analytical Hierarchy Process

	riteria for Evaluatio
1	Availability
2	Speed
3	Price
4	Reliability
5	Safety

Scale for Evaluation	
1	Equal
2	
3	
4	
5	
6	
7	
8	
9	Strongly Important

	Availabili	Speed	Price	Reliability	Safety
Availabilit	1.00	5.00	4.00	5.00	4.00
Speed	0.20	1.00	2.00	1.00	3.00
Price	0.25	0.50	1.00	2.00	1.00
Reliability	0.20	1.00	0.50	1.00	3.00
Safety	0.25	0.33	1.00	0.33	1.00
TOTAL	1.90	7.83	8.50	9.33	12.00

	Availabilit	Speed	Price	Reliability	Safety	Weights
Availabilit	0.53	0.64	0.47	0.54	0.33	0.5008
Speed	0.11	0.13	0.24	0.11	0.25	0.1651
Price	0.13	0.06	0.12	0.21	0.08	0.1221
Reliability	0.11	0.13	0.06	0.11	0.25	0.1298
Safety	0.13	0.04	0.12	0.04	0.08	0.0822
TOTAL	1.00	1.00	1.00	1.00	1.00	1

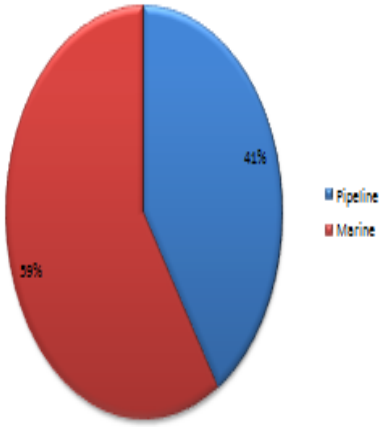
EVALUATION OF CHOICES:

	Availabili	Speed	Price	Reliability	Safety
Pipeline	4	4	5	8	6
Marine	8	6	8	3	8
TOTAL	12	10	13	11	14

	Availabili	Speed	Price	Reliability	Safety
Pipeline	0.33	0.40	0.38	0.73	0.43
Marine	0.67	0.60	0.62	0.27	0.57
TOTAL	1.00	1.00	1.00	1.00	1.00

AHP RESULTS	
Pipeline	0.410
Marine	0.590

AHP RESULTS



Consistency Index $CI=(\lambda max-n)/(n-1)$

λ_max	Eigen Value	5.4
n	Matrix size	5
CI		0.1008

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consiste	0	0	0.6	0.9	1.1	1.2	1.32	1.41	1.5	1.5

Consistency Ratio $CR=(Consistency\ Index)/(Random\ Consistency)$

CR	0.09

Decision Criteria	Acceptable

Source: Author's Computation.

TABLE 4.2: ANALYTICAL HIERARCHY PROCESS MODEL OF PIPELINE AND MARINE TRANSPORTATION MODES. AVAILABILITY PRIORITY.

Decision support system for selecting the best Transportation Mode using Analytical Hierarchy Process

	riteria for Evaluatio
1	Availability
2	Speed
3	Price
4	Reliability
5	Safety

Scale for Evaluation	
1	Equal
2	
3	
4	
5	
6	
7	
8	
9	Strongly Important

Priority: Availabili

	Availabili	Speed	Price	Reliability	Safety
Availabilit	1.00	9.00	9.00	9.00	9.00
Speed	0.11	1.00	1.00	1.00	1.00
Price	0.11	1.00	1.00	1.00	1.00
Reliability	0.11	1.00	1.00	1.00	1.00
Safety	0.11	1.00	1.00	1.00	1.00
TOTAL	1.44	13.00	13.00	13.00	13.00

						Weights
Availabilit	0.69	0.69	0.69	0.69	0.69	0.6923
Speed	0.08	0.08	0.08	0.08	0.08	0.0769
Price	0.08	0.08	0.08	0.08	0.08	0.0769
Reliability	0.08	0.08	0.08	0.08	0.08	0.0769
Safety	0.08	0.08	0.08	0.08	0.08	0.0769
TOTAL	1.00	1.00	1.00	1.00	1.00	1

EVALUATION OF CHOICES:

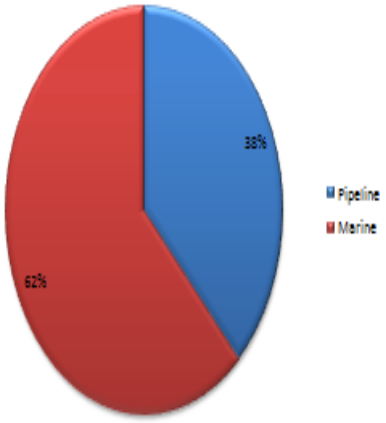
	Availabili	Speed	Price	Reliability	Safety
Pipeline	4	4	5	8	6
Marine	8	6	8	3	8
TOTAL	12	10	13	11	14

	Availabili	Speed	Price	Reliability	Safety
Pipeline	0.33	0.40	0.38	0.73	0.43
Marine	0.67	0.60	0.62	0.27	0.57
TOTAL	1.00	1.00	1.00	1.00	1.00

AHP RESULTS

Pipeline	0.380
Marine	0.620

AHP RESULTS



Consistency Index: $CI=(\lambda max-n)/(n-1)$

λ_max	Eigen Value	5
n	Matrix size	5
CI		0

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consiste	0	0	0.6	0.9	1.1	1.2	1.32	1.41	1.5	1.5

Consistency Ratio: $CR=(Consistency\ Index)/(Random\ Consistency)$

CR: 0

Decision Criteria: Acceptable

Source: Author's Computation

TABLE: 4.3 ANALYTICAL HIERARCHY PROCESS MODEL OF PIPELINE AND MARINE TRANSPORTATION MODES. SPEED PRIORITY.

Decision support system for selecting the best Transportation Mode using Analytical Hierarchy Process

	riteria for Evaluatio
1	Availability
2	Speed
3	Price
4	Reliability
5	Safety

Scale for Evaluation	
1	Equal
2	
3	
4	
5	
6	
7	
8	
9	Strongly Important

Priority: Speed

	Availabili	Speed	Price	Reliability	Safety
Availabilit	1.00	0.11	1.00	1.00	1.00
Speed	9.09	1.00	9.00	9.00	9.00
Price	1.00	0.11	1.00	1.00	1.00
Reliability	1.00	0.11	1.00	1.00	1.00
Safety	1.00	0.11	1.00	1.00	1.00
TOTAL	13.09	1.44	13.00	13.00	13.00

						Weights
Availabilit	0.08	0.08	0.08	0.08	0.08	0.0767
Speed	0.69	0.69	0.69	0.69	0.69	0.6928
Price	0.08	0.08	0.08	0.08	0.08	0.0768
Reliability	0.08	0.08	0.08	0.08	0.08	0.0768
Safety	0.08	0.08	0.08	0.08	0.08	0.0768
TOTAL	1.00	1.00	1.00	1.00	1.00	1

EVALUATION OF CHOICES:

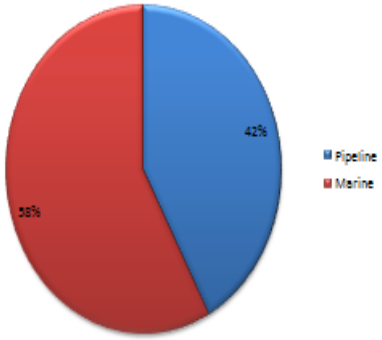
	Availabili	Speed	Price	Reliability	Safety
Pipeline	4	4	5	8	6
Marine	8	6	8	3	8
TOTAL	12	10	13	11	14

	Availabili	Speed	Price	Reliability	Safety
Pipeline	0.33	0.40	0.38	0.73	0.43
Marine	0.67	0.60	0.62	0.27	0.57
TOTAL	1.00	1.00	1.00	1.00	1.00

AHP RESULTS

Pipeline	0.421
Marine	0.579

AHP RESULTS



Consistency Index: $CI=(\lambda_{max}-n)/(n-1)$

λ_max	Eigen Value	5
n	Matrix size	5
CI		0

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consiste	0	0	0.6	0.9	1.1	1.2	1.32	1.41	1.5	1.5

Consistency Ratio: $CR=(Consistency\ Index)/(Random\ Consistency)$

CR: 0

Decision Criteria: Acceptable

Source: Author's Computation

V CONCLUSION

The research has shown that marine transportation mode has priority value of 0.590 while pipeline is 0.410 on a base case scenario. When speed is given priority with respect to other criteria, priority value for marine is 0.579 while pipeline is 0.421. When availability criterion is considered marine priority is 0.620 while that of pipeline is 0.380. The study has established that for relatively long distance, marine transportation mode is preferred to pipeline for marketing of GTL products from Nigeria to overseas

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NOMENCLATURE

AHP - Analytical Hierarchy process.
CI – Consistency Index.
CR – Consistency Ratio.
DWT – Dead weight.
DSS – Decision Support System.
EGTL. – Escravos gas to liquid .
GT – Gross Tons.
GTL – Gas to liquid.
IRTEMP – Infra red Temperature.
ITEMP – Instant read thermometer temperature.
LPG – Liquified petroleum gas.
NPSH – Net Positive Suction Head
RC – Random Consistency.
RVP – Reid Vapour pressure.
TVP – True Vapour pressure
ULCC – Utra large crude carriers.
VLCC – Very large crude carriers.