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## Material Selection for Subsea Pipeline Construction under Uncertainties for Niger Delta Region

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#### Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

#### Article Information

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### ABSTRACT

This research work on material selection for subsea pipeline construction was carried out to analyze and recommend suitable material option that satisfies DNV-OS-F101 standard for subsea pipeline constructions which will not succumb to extreme conditions and performs well in unpredictable conditions in the Niger Delta Region of Nigeria. Crude oil is mainly transported through pipelines, structural failure of the pipelines will severely affect oil production processes and will cause huge economic loss. Data on oil pipeline failures in the Niger Delta region of Nigeria were gathered and the major causes were; corrosion, operational error, third party activities and mechanical failures which were associated with the construction materials and structures of the pipelines. Hence, material selection for subsea pipelines is of vital importance. This paper makes use of Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) Theory to make fuzzy evaluation of different material options for pipeline construction. Statistical data and experts' knowledge were integrated in addressing data limitation. This paper utilizes related weights and normalized scores based on experts' judgements and with the aid of value engineering (VE) method, material criteria based on DNV-OS-F101 standard and TOPSIS Theory to achieve the best material option. The analysis has demonstrated that the estimation of TOPSIS is reliable. The outcome obtained can be used to assist the decision maker in the selection of the best material option suitable for the construction of subsea pipeline in Niger Delta region.

Keywords: Pipelines; material; construction; TOPSIS.

#### **1. INTRODUCTION**

Subsea pipelines are laid on the seabed or below it inside a trench [1,2]. Subsea pipelines are used primarily to carry crude oil or gas. [2] A distinction is sometimes made between a flowline and a pipeline. [1] [2] [3] A flowline is used to connect subsea well heads, manifolds and the platform within a particular development field. A pipeline is used to bring the resource to shore. [1] Pipeline construction projects need to take into account many factors such as environmental loadings, the offshore ecology, mechanical properties of the materials to be used for the pipeline construction so as to overcome buckling, collapse and rupture of the pipeline which are caused by corrosion, high temperature and pressure of the transported fluid.

This work aims at analyzing and recommending suitable cost effective material option that satisfies DNV-OS-F101 standards for subsea pipeline construction and performs well in unpredictable conditions in the Niger Delta region of Nigeria. The Niger Delta region is located in the Southern part of Nigeria and covers about 70,000 km<sup>2</sup> (27,000 Sq Mi) and makes up to 7.5% of Nigeria's land mass. Nigeria is West Africa's biggest producer of petroleum. Some 2 million barrels (320,000m<sup>3</sup>) a day are extracted in the Niger Delta region of the country. It is estimated that 38 billion barrels of crude oil still reside under the delta as of early 2012. [4] These crude is being transported with the aid of subsea pipelines, hence, material selections for subsea pipelines is vital in order to prevent structural failure of pipelines which will severely cause huge economic loss in the cause of oil production in the Niger Delta region.

Researchers have immensely contributed in material selections for subsea pipelines using various methodologies as evidenced by El-Mogi, Hossam [5] where his process was based on corrosion rate calculations and he continued in comparing the different mechanical corrosion resistance properties of corrosion resistant alloys with carbon steel. Ram Narayanaswamy [6] highlighted the selection of pipeline materials based on the consideration of design. construction, operations, maintenance, threats, hazards, risks, safety and economic aspects. He added that metallic and non-metallic materials can be considered for pipeline systems such as steels, reinforced plastics and high-density polyethylene. Yutaek Seo [7], highlighted that pipeline materials should be determined considering parameters such as the conveyed fluid properties and temperature, pipe material cost, installation cost and operational cost. He also made analysis of several piping materials used for oil and gas transportations such as low carbon steel, flexible pipe, CRA pipes and composite pipes. Only limited works are found in existing literature with respect to subsea pipeline material selection using Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method to make fuzzy evaluations. Karan Sotoodeh [8] in his work "Analysis and improvement of Material Selection for process piping system in offshore industry" incorporated well-known methods of screening: three Cambridge material selector, Value Engineering (VE) and technique for order of preference by similarity to ideal solution (TOPSIS) tomake material analysis of six material alternatives.

The significance of this study is to analyze and recommend suitable material option that will not succumb to extreme conditions and performs well in unpredictable conditions in the Niger Delta Region.

#### 2. METHODOLOGY

Topsis method is a multi-criterial decision analysis method, which was originally developed by Chung-Lai Hwang and Yoon in 1981 [9] with further development by Yoon in 1987, [10] and Hwang, Lai and Liu in 1993 [11]. Topsis is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution [12] and the longest geometric distance from the negative ideal solution (NIS) [9]. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalization is usually required as the parameters or criteria are often of incongruous dimensions in multi-criteria problems. [13] [14] Compensatory methods such as TOPSIS allows trade-offs between criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modelling

than non-compensatory methods, which include or exclude alternative solutions based on hard cut-offs [15]. It is one of the best multi-criteria decision-making methods that can be used to select the best material option for subsea pipeline construction in the Niger Delta region. The importance of the TOPSIS method has been illustrated in various research works.

#### 2.1 Steps of TOPSIS

Step 1: Construction of normalized decision matrix.

- This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria.
- Normalize scores or data as follows;

$$\gamma_{ij} = x_{ij} / (\sum x_{ij}^2)^{\frac{1}{2}}$$
 for i = 1, ..... M: j = 1, ...., n

Step 2: Construction of the weighted normalized decision matrix.

- If we have a set of weights for each criteria W<sub>i</sub> for j =1, ....n.
- Multiply each column of the normalized decision matrix by it's associated weight.
- An element of the new matrix is; V<sub>ii</sub> = W<sub>i</sub>, r<sub>ii</sub>

Step 3: Determination of the ideal and negative ideal solutions

Ideal solution

 $\begin{array}{l} A^{*} = \{ \ v_{1}^{*}, \ldots, \ v_{n}^{*} \ \} \ where \\ V_{j}^{*} = \{ \ max \ (v_{ij}) \ if \ j \ \varepsilon \ J^{i} \ \} \end{array}$ 

Negative ideal solution

 $A^{l} = \{V_{1}^{l}, \dots, V_{n}^{l}\}, \text{ where } \\ v^{l} = \{\min(v_{ij}) \text{ if } j \in J; \max(v_{ij}) \text{ if } j \in J^{l}\}$ 

Step 4: Calculating the separation measures for each alternative.

• The separation from the ideal alternative is

$$S_{i}^{*} = \left[\sum_{i} (v_{j}^{*} - v_{ij})^{2}\right]^{1/2}$$
  $i = 1, ...., m$ 

• Similarly, the separation from the negative ideal alternative is;

$$S_{i}^{l} = \left[\sum (v_{j}^{l} - v_{ij})^{2}\right]^{\frac{1}{2}}$$
  $i = 1, ...., m$ 

Step 5: Calculating for the relative closeness to the ideal solution  $c^{\star}_{i}$ 

$$C_{1}^{*} = S_{i}^{I} / (S_{i}^{*} + S_{i}^{I}), \quad 0 < C_{i}^{*} < 1$$

Step 6: Rank the alternatives by selecting the alternative with  $C_{i}$  closet to 1.

3. APPLICATION OF TOPSIS IN THE SELECTION OF SUITABLE MATERIAL OPTION FOR SUBSEA PIPELINE CONSTRUCTION IN NIGER DELTA REGION

In view of this, related weights and normalized scores were given to each material options based on experts' judgements and with the aid of value engineering (VE) method. Materials criteria were based on DNV-OS-F101 standard and statistical data gotten from the summary of various causes of oil pipeline failure in the Niger Delta region.

# 3.1 Determination of Hierarchy Using Value Engineering (VE)

Value Engineering (VE) is a systematic indices and weighting properties method (WPM) implemented for quantitative analysis [16]. A comparison presented in Table 2 is used to determine the weight values and hierarchy. A value of either 0 or 1 is assigned to the matrix for

Table 1. A summary of the various causes of oil pipeline failure in the Niger Delta region ofNigeria

Mechanical Failure	Corrosion	Operational Failure	Third-Party Activity	Natural Hazard
Construction material and structural	Internal, external	Human system	Accidental, malicious (sabotage) incidental and acts of vandalism	Subsidence, flooding and others

Source; Pipeline oil spill prevention and remediation in NDA, NNPC, 2007

each compared pair, depending on which is more important. At the end of the comparison and assigning of scores, the score of each criterion is calculated, the hardness of the material and the resistance of the material to high temperature were the most important criteria with scores 0.29 and 0.24 respectively.

### 3.2 Experts' Analysis

Using the criteria rating scale, the material options rating of hardness fracture toughness, fatigue resistance, resistance to high temperature and cost were respectively estimated by expert 1 as; carbon steel = [5,4,4,1,5,4], stainless steel = [4,4,3,3,5,5], glass reinforced epoxy = [4,3,4,5,3,3], HDPE = [3,3,4,5,3,3], POM = [4,4,4,5,3,3], aluminum alloy

= [3,3,3,4,4,5], PTFE = [3,2,3,5,4,3] and ETFE = [4,3,3,5,3,2]. Expert 2 in the same manner rated carbon steel as [5,5,5,0,5,3], stainless steel = [ reinforced 4,4,4,5,5], glass epoxy = [4,4,3,5,3,3], HDPE = [3,4,4,5,3,3], POM = [3,4,4,5,3,3], aluminum alloy = [3,3,3,3,4,5], PTFE = [3,3,3,5,4,3] and ETFE = [4,3,2,5,3,3]. In a similar way, applying same procedure, used by Experts 1 and 2, Expert 3 rated carbon steel as [5,4,3,1,4,4], stainless steel = [4,4,3,3,4,5], glass reinforced epoxy = [4,3,4,5,3,3], HDPE = [3,3,4,5,3,3], POM = [4,4,3,5,3,2], aluminum alloy = [3,3,4,4,4,5], PTFE = [3,2,3,5,3,3] and ETF = [3,3,3,5,3,2]. The average of the rating scores by the three Experts were found to arrive at the final rating scores (normalized scores in Table 4) assigned to each material option in respect to each material criteria.

#### Table 2. Hierarchy (Weight) Determination Matrix

Criteria	<b>C</b> <sub>1</sub>	<b>C</b> <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	Total Score	Normalized Weight
C <sub>1</sub>	1	1	1	1	1	1	6	0.29
C <sub>2</sub>	0	1	0	0	0	0	1	0.05
C <sub>3</sub>	0	1	1	1	0	1	4	0.19
C <sub>4</sub>	0	1	0	1	0	1	3	0.14
$C_5$	0	1	1	1	1	1	5	0.24
$C_6$	0	1	0	0	0	1	2	0.09
							21	1

*C*<sub>1</sub>: Hardness, *C*<sub>4</sub>: Corrosion Resistance, *C*<sub>2</sub>: Fracture Toughness, *C*<sub>5</sub>: Resistance to High Temperature, *C*<sub>3</sub>: Fatigue Resistance, *C*<sub>6</sub>: Cost

#### Table 3. Criteria rating scale

Very poor	Poor	Okay	Good	Very good
1	2	3	4	5

#### Table 4. Illustrative TOPSIS matrix for material selection for subsea pipeline construction under uncertainties for Niger Delta Region

			Material C	Criteria		
Material option	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost
Carbon steel (C.S)	5	4	4	1	5	4
Stainless steel (S.S)	4	4	3	3	5	5
Glass reinforced expoxy (GRE)	4	3	4	5	3	3
Polyethylene (HDPE)	3	3	4	5	3	3
Polyoxymethylene (POM)	4	4	4	5	3	2
Aluminum Alloy (A.A)	3	3	3	4	4	5
Polytetrafluoroethylene (PTFE)	3	2	3	5	4	3
Ethylene tetrafluoroethylene (ETFE)	4	3	3	5	3	2

The square root of the summation of the squares of the normalized scores  $[(\sum x^2_{ij})^{y_2}]$  for each column was used to divide each normalized score to obtain the elements in the new matrix  $(\gamma_{ii})$ .

Each column of the normalized decision matrix was multiplied by it's associated weight  $(w_j)$  highlighted in Table 2 to obtain the element of the new matrix  $(v_{ij})$ 

The ideal solution denoted as A\* (The highest element) will determined in every column. The

ideal solution for the cost column is the lowest element since we are considering a cost benefit option.

The ideal solution obtained were;  $A^* = [0.133, 0.022, 0.076, 0.057, 0.110, 0.018].$ 

To determine the separation of each element in the column from the ideal solution, the ideal solution was subtracted from the weighted normalized TOPSIS matrix  $(v_{ij})$  for each column and the square of the result was obtained as shown in Table 8.

# Table 5. Illustrative normalized TOPSIS matrix ( $\gamma_{ij}$ ) for material selection for subsea pipeline construction under uncertainties for Niger Delta Region

	Material criteria							
Material Options	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost		
C.S	0.46	0.43	0.40	0.08	0.46	0.40		
S.S	0.37	0.43	0.30	0.24	0.46	0.50		
GRE	0.37	0.32	0.40	0.41	0.28	0.30		
HDPE	0.28	0.32	0.40	0.41	0.28	0.30		
POM	0.37	0.43	0.40	0.41	0.28	0.20		
A.A	0.28	0.32	0.30.	0.33	0.37	0.50		
PTFE	0.28	0.21	0.30	0.41	0.37	0.30		
ETFE	0.37	0.32	0.30	0.41	0.28	0.20		

 Table 6. Illustrative weighted normalized TOPSIS matrix (v<sub>ij</sub>) for material selection for subsea

 pipeline under uncertainties for Niger Delta Region

	Material criteria							
Material	Hardness	Fracture	Fatigue	Corrosion	Resistance to	Cost		
Options		toughness	resistance	resistance	high temperature			
C.S	0.133	0.022	0.076	0.011	0.110	0.036		
S.S	0.107	0.022	0.057	0.034	0.110	0.045		
GRE	0.107	0.016	0.076	0.057	0.067	0.027		
HDPE	0.081	0.016	0.076	0.057	0.067	0.027		
POM	0.107	0.022	0.076	0.057	0.067	0.018		
A.A	0.081	0.016	0.057	0.046	0.089	0.045		
PTFE	0.081	0.011	0.057	0.057	0.089	0.027		
ETFE	0.107	0.016	0.057	0.057	0.067	0.018		

 
 Table 7. Illustrative TOPSIS matrix showing ideal solutions (A\*) for material selection for subsea pipeline construction under uncertainties for Niger Delta Region

	Material criteria									
Material Options	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost				
	0 133	0.022	0.076	0.011	0 110	0.036				
0.0	0.155	0.022	0.070	0.011	0.110	0.000				
S.S	0.107	0.022	0.057	0.034	0.110	0.045				
GRE	0.107	0.016	0.076	0.057	0.067	0.027				
HDPE	0.081	0.016	0.076	0.057	0.067	0.027				
РОМ	0.107	0.022	0.076	0.057	0.067	0.018				
A.A	0.081	0.016	0.057	0.046	0.089	0.045				
PTFE	0.081	0.011	0.057	0.057	0.089	0.027				
ETFE	0.107	0.016	0.057	0.057	0.067	0.018				

			Mate	rial Criteria		
Material Options	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost
C.S	(.133133) <sup>2</sup>	$(.022022)^2$	$(.076076)^2$	(.011057) <sup>2</sup>	(.110110) <sup>2</sup>	(.036018) <sup>2</sup>
S.S	(.107133) <sup>2</sup>	$(.022022)^2$	$(.057076)^2$	$(.034057)^2$	(.110110) <sup>2</sup>	(.045018) <sup>2</sup>
GRE	$(.107133)^2$	$(.016022)^2$	$(.076076)^2$	$(.057057)^2$	$(.067110)^2$	$(.027018)^2$
HDPE	$(.081133)^2$	$(.016022)^2$	$(.076076)^2$	$(.057057)^2$	$(.067110)^2$	$(.027018)^2$
POM	$(.107133)^2$	$(.022022)^2$	$(.076076)^2$	$(.057057)^2$	$(.067110)^2$	$(.018018)^2$
A.A	$(.081133)^2$	$(.016022)^2$	$(.057076)^2$	$(.046057)^2$	$(.089110)^2$	(.045018) <sup>2</sup>
PTFE	$(.081133)^2$	$(.011022)^2$	$(.057076)^2$	$(.057057)^2$	$(.089110)^2$	$(.027018)^2$
ETFE	(.107133) <sup>2</sup>	(.016022) <sup>2</sup>	$(.057076)^2$	$(.057057)^2$	$(.067110)^2$	(.018018) <sup>2</sup>

# Table 8. TOPSIS matrix $[(v_j^* - v_{ij})^2]$ to determine the separation from ideal solution (A\*)

Table 9. Illustrative TOPSIS matrix to determine the separation from ideal solution

	Material Criteria						
Material Options	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost	
C.S				0.002116		0.000324	
S.S	0.000676		0.000361	0.000529	<u> </u>	0.000729	
GRE	0.000676	0.000036			0.001849	0.000081	
HDPE	0.002704	0.000036			0.001849	0.000081	
РОМ	0.000676				0.001849		
A.A	0.002704	0.000036	0.000361	0.000121	0.000441	0.000729	
PTFE	0.002704	0.000121	0.000361		0.000441	0.000081	
ETFE	0.000676	0.000036	0.000361		0.001849		

The summation of the values in each row were made to obtain  $\sum (v_j^* - v_{ij})^2$ . The square root of  $\sum (v_j^* - v_{ij})^2$  was obtained for each row to get si<sup>\*</sup>.

The negative ideal solution denoted as A<sup>I</sup>(The lowest element) were determined in every column. The negative ideal solution for the cost column is the highest value since weare also considering a cost benefit material option as shown in Table 11.

The negative ideal solution denoted as  $A^{I}$  obtained were,  $A^{I} = [0.081, 0.011, 0.057, 0.011, 0.067, 0.045].$ 

To determine the separation of eachelement in the column from the negative ideal solution, the negative ideal solution was subtracted from the weighted normalized TOPSIS matrix ( $V_{ij}$ ) for each column, the square of the result obtained was made as shown in Table 12.

The summation of the values in each row were made to obtain  $\sum (v_i^l - v_{ij})^2$ . The square root of

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 $\sum (v_j^l - v_{ij})^2$  was obtained for each row to get si<sup>l</sup> as shown in Table 14.

To calculate for the relative closeness of the material options to the ideal solution  $(C_i^*)$ , the value of the separation from the negative ideal solution  $(S_i^{l})$  was divided with the result obtained from the addition of the values of the separation of the ideal solution  $(S_i^*)$  and the separation from the negative ideal solution  $(S_i^{l})$  as shown in Table 15.

#### 4. RESULTS AND DISCUSSION

Table 2 presenting the results of the VE study shows that material hardness and it's resistance to high temperature were the criteria with the highest weights with normalized weights of 0.29 and 0.24 respectively, making both criteria the most important criteria in the study. The selection of the best alternative was achieved using TOPSIS method. Initially, there was a set of material criteria which were in line withDNV-OS-F101 standard. The first criteria was material hardness followed by fracture toughness, fatigue resistance, corrosion resistance, resistance to high temperature and then cost.

Material Options	∑(v* <sub>j</sub> - v <sub>ij</sub> )²	$SI^* = [\sum (v_j^* - v_{ij})^2]^{\frac{1}{2}}$
C.S	0.002440	0.04941
S.S	0.002295	0.04791
GRE	0.002642	0.05140
HDPE	0.004670	0.06834
POM	0.002525	0.05025
A.A	0.004392	0.06627
PTFE	0.003708	0.06089
ETFE	0.002922	0.054060

Table 10. TOPSIS matrix to determine the separation from the ideal solution

Table 11. Illustrative TOPSIS matrix showing negative ideal solution (A <sup>I</sup> ) for material selection
for subsea pipeline under uncertainties for Niger Delta Region

	Material Criteria							
Material	Hardness	Fracture	Fatigue	Corrosion	Resistance to	Cost		
Options		toughness	resistance	resistance	high temperature			
C.S	0.133	0.022	0.076	0.011	0.110	0.036		
S.S	0.107	0.022	0.057	0.034	0.110	0.045		
GRE	0.107	0.016	0.076	0.057	0.067	0.027		
HDPE	0.081	0.016	0.076	0.057	0.067	0.027		
РОМ	0.107	0.022	0.076	0.057	0.067	0.018		
A.A	0.081	0.016	0.057	0.046	0.089	0.045		
PTFE	0.081	0.011	0.057	0.057	0.089	0.027		
ETFE	0.107	0.016	0.057	0.057	0.067	0.018		

	Material Criteria					
Material Options	Hardness	Fracture	Fatigue	Corrosion	Resistance to	Cost
_		toughness	resistance	resistance	high temperature	
C.S	(.133081) <sup>2</sup>	(.022011) <sup>2</sup>	$(.076057)^2$	(.011011) <sup>2</sup>	(.110067) <sup>2</sup>	(.036045) <sup>2</sup>
S.S	(.107081) <sup>2</sup>	$(.022011)^2$	$(.057057)^2$	(.034011) <sup>2</sup>	(.110067) <sup>2</sup>	$(.045045)^2$
GRE	(.107081) <sup>2</sup>	$(.016011)^2$	$(.076057)^2$	$(.057011)^2$	$(.067067)^2$	$(.027045)^2$
HDPE	$(.081081)^2$	$(.016011)^2$	$(.076057)^2$	$(.057011)^2$	$(.067067)^2$	$(.027045)^2$
POM	(.107081) <sup>2</sup>	(.022011) <sup>2</sup>	$(.076057)^2$	(.057011) <sup>2</sup>	$(.067067)^2$	(.018045) <sup>2</sup>
A.A	(.081081) <sup>2</sup>	$(.016011)^2$	$(.057057)^2$	(.046011) <sup>2</sup>	$(.089067)^2$	$(.045045)^2$
PTFE	(.081081) <sup>2</sup>	$(.011011)^2$	$(.057057)^2$	$(.057011)^2$	$(.089067)^2$	$(.027045)^2$
ETFE	(.107081) <sup>2</sup>	(.016011) <sup>2</sup>	$(.057057)^2$	$(.057011)^2$	$(.067067)^2$	$(.018045)^2$

# Table 12. TOPSIS matrix $[(v_j^l - v_{ij})^2]$ to determine the separation from the negative ideal solution (A<sup>l</sup>)

Table 13. Illustrative TOPSIS matrix to determine the separation from ideal solution

	Material Criteria					
Material Options	Hardness	Fracture toughness	Fatigue resistance	Corrosion resistance	Resistance to high temperature	Cost
C.S	0.002704	0.000121	0.000361		0.001849	0.000081
S.S	0.000676	0.000121		0.000529	0.001849	
GRE	0.000676	0.000025	0.000361	0.0002116		0.000324
HDPE		0.000025	0.000361	0.002116		0.000729
POM	0.000676	0.000121	0.000361	0.002116		0.000729
A.A	—	0.000025		0.001225	0.000484	
PTFE				0.002116	0.000484	0.000324
ETFE	0.000676	0.000025		0.002116		0.000729

Material Options	$\sum (v_{i}^{i} - v_{ii})^{2}$	$SI' = [\sum (v'_i - v_{ij})^2]^{\frac{1}{2}}$	
C.S	0.005116	0.07153	
S.S	0.003175	0.05635	
GRE	0.003502	0.05918	
HDPE	0.002826	0.05316	
POM	0.004003	0.06327	
A.A	0.001734	0.04164	
PTFE	0.002924	0.05407	
ETFE	0.003546	0.05955	

Table 14. TOPSIS matrix to determine the separation from the negative ideal solution

Table 15. T	OPSIS	matrix (C <sub>i</sub> *	) showing	the relative	e closeness	of the	material	options 1	to the
				ideal soluti	on				

	Si <sup>l</sup> /(Si* + Si <sup>l</sup> )	Ci* = Si <sup>1</sup> / (Si* + Si <sup>1</sup> )	
C.S	0.07153/0.12094	0.59	
S.S	0.05635/0.10426	0.54	
GRE	0.05918/0.11058	0.53	
HDPE	0.05316/0.12150	0.43	
РОМ	0.06327/0.11352	0.55	
A.A	0.04164/0.10791	0.38	
PTFE	0.05407/0.11496	0.47	
ETFE	0.05955/0.11361	0.52	

Based on the assessments by pipeline experts in terms of the subsequent criteria, a decision matrix was developed (Table 4). A normalized (vector-based) matrix (Table 5) was developed. The weighted normalized decision matrix (Table 6) was also developed. The next approach involved the recognition of the positive ideal solution  $(A^*)$  and the negative ideal solution  $(A^I)$ . after selecting the distance measure, the separation measures  $S_i^*$  and  $S_i^I$  of each alternative were calculated from the intuitionistic fuzzy positive ideal and negative ideal solutions. The relative closeness coefficient was calculated. As result (Table 15) carbon steel was found to be the best material option among these alternatives with a relative closeness to ideal solution 0.59 which was the closest value to 1 overtaking it competitor polyoxymethylene (POM) which had a relative closeness of 0.55. stainless steel ranked third followed by glass reinforced epoxy. Ethylene tetrafluoroethylene ranked fifth with a relative closeness of 0.52, polytetrafluorethylene ranked sixth with a relative closeness of 0.47 followed by HDPE with a relative closeness of 0.43 leaving aluminum alloy last with a relative closeness of 0.38 to the ideal solution.

#### 5. CONCLUSION

Topsis model, a multi-criterial decision analysis method was employed in the search for a costbenefit material option that can be used for subsea pipeline construction in Niger Delta region. In the illustrative example, the model revealed carbon steel as the best alternative among eight other alternatives that are capable of being used for subsea pipeline construction to a certain degree of confidence. Carbon steel has the advantage of high strength, durability, high level of resistance to high temperature and pressure and also has high fatigue resistance. Aluminum alloy was ranked last and has disadvantages of low fatigue resistance level, lesser hardness, fracture toughness and a very high cost compared to carbon steel.

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### **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

#### REFERENCES

- 1. Dean ETR, Reston VA. Offshore geotechnical Engineering Principles and Practice, Thomas Telford, USA. 2010;520.
- Palmer AC, King RA. Subsea Pipeline Engineering (2<sup>nd</sup> Ed.). Tulsa, U.S.A. Pennwell. 2008;624.
- Bai Y, Bai Q. Subsea Engineering Handbook. Gulf professional publishing, New York. 2010;919.
- Isumonah V. Adelfemi. "Armed Society in the Niger Delta". Armed forces & Society. 2013;39(2):331-358.
- 5. El-Mogi, Hossam. "Design of subsea pipeline with respect to corrosion and material selection". Masteroppgave/U.S-TN-1KM; 2016.
- Ram Narayanaswamy. "The process of materials selection for pipeline systems optimization for life cycles" ASME Indian oil and gas pipeline conference. Paper no. 10GPC2017-2404; 2017.
- Yutaek Seo. Offshore projects various equipment. Lecture plan; 2019. Available: https://www.scribd.com
- Karan Sotoodeh. Analysis and improvement of material selection for process piping system in offshore industry. American Journal of Mechanical Engineering. 2018;6:17-26.

- Hwang CL, Yoon K. Multiple Attribute Decision Making: Methods and Applications. New York; Springer-Verlag; 1981
- Yoon K. A reconciliation among discrete compromise situations. Journal of the Operational Research Society. 1987;38(3): 277-286.
- Hwang CL, Lai YJ, Liu TY. A new approach for multiple objective decision making. Computers and Operational Research; 1993.
- Assari A, Maheshs T, Assari E. "Role of public participation in sustainability of historical city; usage of Topsis method". Indian Journal of Science and Technology; 2012.
- Yoon KP, Hwang C. Multiple Attribute Decision Making. An introduction. California: SAGE Publications; 1995.
- Zavadskas EK, Zakarevicius A, Antucheviciene J. Evaluation of Ranking Accuracy in Multi-Criteria Decisions. Informatica. 2006;17(4):601-618.
- 15. Greene R, Devillers R, Luther JE, Eddy BG. GIS-based multi-criteria analysis. Geography compass. 2011;5/6(6):412-432.
- Farag M. Materials selection for engineering design. Prentice-Hall. 1997;227-376.

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