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A Multi-Criteria Decision Making for Location Selection in the Niger Delta Using Fuzzy TOPSIS Approach

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ABSTRACT:
Making an informed decision with regards to a suitable business location or site selection for organizations is becoming challenging for business decision makers globally; and even more challenging in business environment that are saddled with uncertainties. The continues raise of multiple criteria variation of site preferences has also necessitated the application of advanced decision making techniques in handling most business operations. In the light of this, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach to decision making in suitable site selection was used in this study to proffer an ideal location for a residential base camp for a multinational oil company (MNOC). A decision matrix of 16 towns was developed and the criteria for selection of suitable location for residential base camp include availability of land, expansion possibilities, logistics cost, and proximity to oil and gas facilities and natural disaster (flooding). The suitable site location selection was achieved by analyzing the weighted matrix criterion and relative closeness coefficient to the positive ideal solution and the distance from the negative ideal solution. The study found that the positive ideal solution for the site location is Erema represented by code (B3), followed by Amah (B2) and Obiozimini (B12) composed of all best values attainable for the criteria used in the study. The study provided an insight into MCDM for residential base camp location selection for companies when considering suitable location for residential or any other business purposes in the OML 58, Niger Delta, Nigeria.

Keywords: *TOPSIS, Fuzzy environment, Niger Delta, Multi-criteria decision making, Location selection*

INTRODUCTION

Making an informed decision with regards to a suitable business location or site selection for organizations is becoming challenging for business decision makers globally (Alberto, 2000; Chu, 2002a) and even more challenging in business environment that are saddled with uncertainties (Chen and Tsao, 2008); which consequently has increased operational cost and decreased market shares of companies (Chen, 2001). The decision making process are sometimes dependent on location spatial position against operational outcomes in a fuzzy environment (Chu and Lin, 2002); therefore a multi criteria decision making (MCDM) that involves the technique for order preference by similarity to the ideal solution (TOPSIS), which emphasizes that the selected alternatives should have the least distance with positive ideal solution and the most distance with negative ideal solution(Colson and Dorigo, 2004; Ho et al., 2010; Zaeri et al., 2011) has severally been applied in location and suppliers selection research. The TOPSIS approach to decision making in suitable site selection is used in this

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study to proffer an ideal site location for a multinational oil company (MNOC), Total Exploration and Production company (TEPNG) residential base camp in the Niger Delta, Nigeria. 16 Towns (Oboburu, Amah, Erema, Rumuekpe, Obite, Akabuka, Egita, Ede, Ohali, Akabta, Ibewa, Obiozimini, Ogbigbor, Obiyebe, Obukaegi, and Itu-Ogba) were selected in one of the operational area of the company called Oil mining licence (OML58). There are existing residential base camps in towns such as Obagi and Ogbogu but the impact of uncertainties in the recent past has adversely impacted on the company's operation and has significantly increased the logistics cost and loss of revenue particularly with natural disasters such as flooding. Decision making using TOPSIS in previous studies has considered variables that includes but not limited to warehouse facilities (Drezner et al., 2003; Demirel et al., 2010; Ashrafzadeh et al., 2012), Quality improvement (Saremi et al., 2009; Mehrparvar et al., 2012; Erdogan et al., 2013), Trans-shipment site location (Onut and Soner, 2008), New Towns (Asadzadeh et al., 2014); Facility location (Ishii et al., 2007; Awasthi et al., 2011; Li et al., 2011). The selection criteria available in literature included inter alia proximity to high way, availability of utilities such as gas and electricity, labor relations, industry regulations among others.

The five criteria used in this study include: Availability of land, Expansion possibilities, Logistics cost, proximity to oil and gas facilities, and natural disaster (flood) impact. With the help of relevant literature including opinion of experts in operations management research, the author extrapolated variables and effective criteria in the selection of suitable base camp location for TEPNG in OML 58. The selected criteria were evaluated and the weight determined and ranked by implementing (TOPSIS) approach in the decision making.

Factoring any given TOPSIS criteria and alternative variables into location decision, relies on the efficiency and level of responsiveness of strategic management to uncertainties that occur in daily operations; including that of the understanding of sustainable infrastructural capacity development and supply chain networks for competitive advantage. The continues raise of multiple variation of site preferences including industry regulations has also necessitated the application of advanced decision making techniques in handling most business operations.

Literature Review

There has been studies on location selection problems in operations and supply chain management; ranging from warehouse selection topics to determining the most appropriate location for logistics centers, hotels and airports. In most site selection projects, it is often challenging to develop selection criteria that can precisely represent the best preferred site over alternatives (Ho et al., 2013; Chen et al., 2014). As different criteria and decisions are made in multidimensional space, the selection of appropriate method for assessing of desired alternatives is very important (Kuo, 2011). Decision impact in location decisions can be short term or can rise over long term period and have significant consequences in socio-economic aspects of business operations (Chu, 2002b; Asadzadeh et al., 2014). In determining an optimal site selection process for residential settlements, operational objectives and determination of alternatives remains crucial, and decision is based on relative fitness of each alternative, thus, the desired variable is selected (Zebardast, 2001; Chou, 2008); and factors such as availability of a water supply, good road network, gas and electricity utility services, potentialities for sewage and solid waste disposal and the suitability of the land for development are usually considered paramount in the decision agenda (Awasthi et al., 2011; Asadzadeh et al., 2014). Nonetheless, site location problem often involves a pool of locations alternatives that are evaluated against other sets of weighted criteria as independent variables; and the alternative that is eligible with respect to all criteria is thereafter selected for implementation (Awasthi et al., 2011). Traditionally operations research optimization problems deals with optimization of a single objective function against a set of feasible solutions but MCDM applies mostly in making decisions in the presence of multiple scenario involving conflicting alternatives and non-commensurable criteria (Chou et al., 2008); Thus, site selection can be viewed as a Multiple Criteria Decision Making (MCDM) or it may be a Multiple Attributes Decision-Making (MADM) problems (Turskis and Zavadskas, 2010; Ho et al., 2013). The inherent features of this decision is most times unstructured and involves trade-off among multiple variables that include both qualitative and quantitative factors but regardless of whether it is MCDM or MADM that is selected, both approaches deals with the selection and ranking of one or more sites from an alternative (Li et al., 2011; Fazli and Jafari, 2012). These techniques have been primarily developed to assist decision makers in either ranking a known set of alternatives for a problem or making a choice among the sets while considering the conflicting alternatives (Mahdavi et al., 2008). A further literature review shows that combination of geographical information system (GIS) and analytical hierarchy process (AHP) procedure were applied to assist in site selection (Vlachopoulou et al., 2001; Ertugrul and Karakasglu, 2008). While (Kamf et al., 2011; Li et al., 2011) developed a fuzzy multi-attribute decision making approach for distribution hub location selection problem; and qualitative criteria paradigm has also been utilized that included criteria such as transportation, commercial area, environmental factors, traffic conditions, geographic conditions, hotel characteristics, and operation management variables (MacCarthy and Atthrirawong, 2003; Yong, 2006; Wang and Chang, 2007). Strength weakness opportunity and treats (SWOT) analysis for business operations evaluation was used to determined suitable location for businesses using criteria such as Costs, labor demographics, infrastructure; and markets forces has also been studied in a fuzzy environment to support the decision-making process for strategic purposes (Lee and Lin, 2008; Marbini and Saatib, 2009; Ying, 2010; Azimi et al., 2011; Alptekin, 2013).

Facility location decision usually involves firms search to locate or expand their business operations by finding the lowest viable cost variable for logistics and operations management from multiple origins to destinations (Yong, 2006; Shyur, 2006). The decision making process encompasses the identification, evaluation, analysis, and selection among optimum alternatives (Chen, 2001; Chou et al., 2008). Selecting a facility location is a very important decision for organizations due to the operational cost implication and often challenging to reverse; such major decision also requires a long term management commitment (Chu, 2002a; Choudhary and Shankar, 2012; Kumar and Kumanan, 2012).

For instance a poor logistics hub location decision may result in an increase in haulage costs, increased transit time, and decreased competitive edge. Although many studies that utilized TOPSIS techniques have been used to determine a suitable business sites of various purposes and dimensions, the lack of such studies in site selection of a residential base camp for MNOC in a fussy environment is completely evident from available literatures that were reviewed by the author. Site selection from urban scholars' perspective is that rather than standard empirical approach, administrative convenience and political factors tends to be more dominant in decision making process of new site selection (Asadzadeh et al., 2014).

RESEARCH METHOD

Utilizing an appropriate method for the purpose of this study remains a critical issue in the selection of a suitable site for a residential base camp and has also shown to be a multiple criteria decision making (MCDM) problem which include the use of technique for order preference by similarity to ideal solution (TOPSIS) (Hwang and Yoon, 1981; Wang and Elhag, 2006; Yang, 2007; Chen et al., 2014). TOPSIS technique provides an important connection within criteria and identifies most suitable preferences in an order of priority (Vimal et al., 2012).

TOPSIS has been adjudged to be among most suitable technique for solving multi criteria decisions problems; and implemented on the bases that an optimal alternative is considered to have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) (Drezner et al., 2003; Awasthi et al., 2011). TOPSIS techniques are valuable decision making processes that assist decision makers to rank priorities in order to manage complex decisions, vagueness and uncertainty in business operations through robust comparative analysis, thereby harmonizing the outcome (Saremi et al., 2009; Chen et al., 2014).

There are various steps involved in the TOPSIS technique utilized in this study that led to the final selection of suitable site location for the residential base camp, and the steps are hereafter presented and discussed.

Step 1: Formation of a decision matrix (table 1) with matrix structured as follows:

$$D = \begin{pmatrix} & B_1\, B_2 \ldots B_j \ldots B_n \\ A_1 & x_{11} x_{12} \ldots x_{1j} .. x_{1n} \\ A_2 & x_{21} x_{22} .. x_{2j} .. x_{2n} \\ : & : : : : \\ A_i & x_{i1}\, x_{i2} \ldots x_{ij} \ldots x_{in} \\ : & : : : \quad : \\ A_m & x_{mi} x_{m2} x_{mj} .. x_{mn} \end{pmatrix} \quad (1)$$

Where Ai = ith alternative i, i=1….,m; and B_j = j^{th} criteria

X_{ij} = the numerical outcome of the i^{th} alternative with respect to each j^{th} criteria

Step 2: Involves normalization of the decision matrix D (table 2) by using:

$$S_{ij} = X_{ij}/\sqrt{\Sigma_j^n X_{ij}^2} \quad (2)$$

i=1….n; j= 1…..m

Step 3: Calculation of the weighted normalized decision matrix (table 3) by multiplying the normalized decision matrix by its associated weights. The weighted normalized value V_{ij} is calculated as:

$$V_{ij} = W_{ij}(S_{ij}) \quad (3)$$

Step 4: Determine the positive ideal solution (PIS) and negative ideal solution (NIS).

$$V^+ = \{(\text{Max } V_{ij} \mid j\epsilon J), (\text{Min } V_{ij} \mid j\epsilon J')\}$$
$$V^- = \{(\text{Min } V_{ij} \mid j\epsilon J), (\text{max } V_{ij} \mid j\epsilon J')\}$$
$$V^+ = (V^+ 1,2,3\ldots Vn^+);\ V^- = (V^- 1,2,3\ldots\ Vn^-)$$

where J is associated with the positive criteria and J' is associated with the negative criteria

Step 5: Calculation of the separation measure invloving positive and negative criteria

The separation of each alternative from the positive ideal criteria (table 4) is as follows:

$$F_i^+ = \sqrt{\Sigma_j^n = 1\ (V_{ij} - V_j^+)^2}$$
where i = 1,2,3…,m (4)

Thus, the separation of each alternative from the negative ideal criteria (table 5) is also given by:

$$F_i^- = \sqrt{\Sigma_j^n = 1\ (V_{ij} - V_j^-)^2}$$
where i = 1,2,3…,m (5)

Step 6: Calculation of the relative closeness to the ideal solution

The relative closeness of A_i with respect to V^+ (Table 6) is defined as:

$E_i^* = F_i^-/(F_1^+ + F_i^-)$, $0 \leq E_i^* \leq 1$; the index value of E_i^* lies between 0 and 1

where i = 1,2,3,4…,m; and the greater the E_i^* value, the better the performance of the alternatives.

Step 7: Ranking the preference order of the index valuesis finally done for decision making

In order to implement the research methodology, the 16 base camp location alternatives: Oboburu, Amah, Erema, Rumuekpe, Obite, Akabuka, Egita, Ede, Ohali, Akabta, Ibewa, Obiozimini, Ogbigbor, Obiyebe, Obukaegi, and Itu-Ogba, are represented by B1, B2, B3…………m, respectively.

The five selection criteria: Availability of land, Expansion possibilities, Logistics cost, proximity to oil and gas facilities, and natural disaster (flooding) impact are represented by C1, C2, C3, C4 and C5 respectively.

Numerical rating was used where applicable to assign weight to the selection criteria as follows:

C1, C2, and C4	C3 and C5
3= Moderate 5= Good;	3= Moderate
7 = Very Good	5= High; 7= Very High
9= Excellent	9=Extreme

Weight: C1=0.3; C2=0.1; C3=0.1; C4=0.1; C5=0.4

Table 1: Decision matrix

Criteria → / Alternatives Location ↓	C1	C2	C3	C4	C5
B1	5	5	3	9	9
B2	7	7	3	5	3
B3	7	5	3	7	3
B4	3	3	3	5	3
B5	3	3	3	9	5
B6	5	3	3	9	5
B7	9	7	3	7	3
B8	7	7	3	7	3
B9	7	5	3	7	9
B10	9	5	3	5	3
B11	9	7	3	5	3
B12	7	7	3	5	3
B13	5	5	3	5	9
B14	7	7	3	7	5
B15	7	5	3	3	3
B16	9	7	5	5	3

Table 2: Normalization of decision matrix

Criteria → / Alternatives Location ↓	C1	C2	C3	C4	C5
B1	0.181	0.221	0.237	0.334	0.383
B2	1.777	0.309	0.237	0.185	0.128
B3	1.777	0.221	0.237	0.259	0.383
B4	0.108	0.133	0.237	0.334	0.383
B5	0.108	0.133	0.237	0.334	0.213
B6	0.181	0.133	0.237	0.334	0.213
B7	0.326	0.309	0.237	0.259	0.128
B8	0.253	0.309	0.237	0.259	0.128
B9	0.253	0.221	0.237	0.259	0.383
B10	0.326	0.221	0.237	0.185	0.128
B11	0.326	0.309	0.237	0.185	0.128
B12	1.777	0.309	0.237	0.185	0.128
B13	0.181	0.221	0.237	0.185	0.383
B14	0.253	0.309	0.237	0.259	0.213
B15	0.253	0.221	0.237	0.111	0.128
B16	0.326	0.309	0.395	0.185	0.128

Table 3: The weighted normalized decision matrix

Criteria → / Alternatives Location ↓	C1	C2	C3	C4	C5
B1	0.054	0.022	0.024	0.033	0.153
B2	0.533	0.031	0.024	0.019	0.051
B3	0.533	0.022	0.024	0.026	0.153
B4	0.032	0.013	0.024	0.033	0.153
B5	0.032	0.013	0.024	0.033	0.085
B6	0.054	0.013	0.024	0.033	0.085
B7	0.098	0.031	0.024	0.026	0.051
B8	0.076	0.031	0.024	0.026	0.051
B9	0.076	0.022	0.024	0.026	0.153
B10	0.098	0.022	0.024	0.019	0.051
B11	0.098	0.031	0.024	0.019	0.051
B12	0.533	0.031	0.024	0.019	0.051
B13	0.054	0.022	0.024	0.019	0.153
B14	0.076	0.031	0.024	0.026	0.085
B15	0.076	0.022	0.024	0.011	0.051
B16	0.098	0.031	0.040	0.019	0.051

Determine the positive ideal solution (PIS) and negative ideal solution (NIS).

$V^+ = \{(\text{Max } V_{ij} \mid j\epsilon J), (\text{Min } V_{ij} \mid j\epsilon J')\}$;

$V^- = \{(\text{Min } V_{ij} \mid j\epsilon J), (\text{max } V_{ij} \mid j\epsilon J')\}$

$V^+ = (V^+ \; 1,2,3\ldots.Vn^+)$; = (0.533; 0.031; 0.040; 0.033; 0.153)

$V^- = (V^- \; 1,2,3\ldots. \; Vn^-)$; = (0.032; 0.013; 0.024; 0.011; 0.051)

Table 4: Separation of the positive ideal criteria (F_i^+)

Location Alternatives	$F_i^+ = \sqrt{\Sigma_j{}^n = 1 \, (V_{ij}-V_j^+)^2}$; where i = B1,2,3,4…,m
B1	0.479
B2	0.104
B3	0.020
B4	0.502
B5	0.506
B6	0.484
B7	0.447
B8	0.469
B9	0.457
B10	0.446
B11	0.447
B12	0.104
B13	0.480
B14	0.462
B15	0.469
B16	0.452

Table 5: Separation of the negative ideal criteria (F_i^-)

Location Alternatives	$F_i^- = \sqrt{\Sigma_j^n = 1\, (V_{ij}-V_j^-)^2}$; where i = B1,2,3,4…,m
B1	0.107
B2	0.501
B3	0.512
B4	0.104
B5	0.040
B6	0.046
B7	0.070
B8	0.050
B9	0.110
B10	0.067
B11	0.068
B12	0.502
B13	0.105
B14	0.060
B15	0.045
B16	0.071

Table 6: Relative closeness coefficient and ranking

Location Alternatives	Closeness coefficient	Rank
B1	0.182	5
B2	0.834	2
B3	0.962	1
B4	0.173	7
B5	0.072	16
B6	0.081	15
B7	0.152	8
B8	0.092	14
B9	0.191	4
B10	0.132	10
B11	0.141	12
B12	0.823	3
B13	0.181	6
B14	0.124	11
B15	0.102	13
B16	0.142	9

RESULTS AND DISCUSSION

The result in this study indicate that the proposed positive ideal solution for the residential base camp location is Erema represented by code (B3) ranked 1st with a closeness coefficient of 0.96, followed by Amah (B2) which has a closeness coefficient score of 0.83 and Obiozimini (B12) with 0.82 closeness coefficient, and they composed of all best values attainable for a given ideal criteria used in the study.

Whereas the negative ideal solution consists of all lower values attainable of each location criteria in the ranked order as presented in table 6. This was achieved by analyzing the criteria relative closeness to the positive ideal solution and the distance from the negative ideal solution. The attributes of the Towns used in this study are interwoven in the order of ranking, because some of Towns may be prone to flooding, which has widened their suitability gap to the positive ideal location ranking, and also closes other suitability criteria gap to the negative ideal location with regards to expansion possibilities and proximity to oil and gas facilities; for instance, Obite (B5) ranked 16th with a closeness coefficient of 0.072, may not necessarily be adversely impacted by flooding but there is currently insufficient land for future expansion due to the recent vast land acquisition by TEPNG that stretches to Egita (B7), which was acquired as a buffer zone because of gas leakage in the area. Egita (B7) is ranked 8th in the relative closeness to ideal solution, with a closeness coefficient of 0.152, although significant land has been acquired as stated above, the availability of land is excellent and expansion possibility is very good, when considering land area that extend towards Amah (B2) and Akabta (B10) respectively and flood impact is considered moderate. In Oboburu (B1), there is also availability of land with good expansion possibility, excellent proximity to facilities but with extreme flood impact with swampy terrain, however the relative closeness ranking is in 5th place with a closeness coefficient of 0.182. Rumuekpe (B4) also has land with expansion possibilities, the impact of flooding is considered moderate and ranked 7th in the relative closeness to suitable ideal location. In Akabuka (B6) there is availability of land, expansion possibilities is considered good and proximity to facilities is excellent but most available land area that stretches to Oboburu (B1) are also prone to flooding, it is ranked 15th with closeness coefficient of 0.081.

All other Towns in the study also follow similar trends, however, the various locations and its relative closeness to the ideal solution ranking were based on inter alia calculations from the weighted decision matrix, measured criteria and the respective closeness coefficient values.

CONCLUSION

This study was necessitated by the fuzziness of the research site, and decision making in a fuzzy environment most times requires an analysis of a multiple criteria for an informed decision making. Natural disaster particularly flooding, is one of such criteria that was used in the study because of its adverse impact on business operations; for instance in the recent past flood had submerged most facilities of TEPNG in OML 58, which forced the company to shutdown operation and relocate their workers to safer locations, leading to increase in logistics cost and decreased return-on-investment in oil and gas fields in most of the affected communities for more than two months. Other criteria for selection of suitable location for the base camp include availability of land, expansion possibilities, logistics cost, and proximity to oil and gas facilities. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was used in the study and according to this technique, the best alternative would be ideal solution and farthest from the negative ideal solution. The word “negative” in this context do not imply that the negative ideal solution is “literally bad” but only suggests that there are other better solution among the measured variables, in a numerical ranking. In other words, positive and negative are often used in a multi criteria decision making(MCDM) especially when using TOPSIS to allocate ideal solutions in an ordered preference.

It is also important to note that the ideal location suitability proposed in this paper is in the context of the criteria used in the research and not necessarily a generalized scenario; because if other criteria were used or a variation of the existing criteria, some of the negative ideal solution would most likely become positive ideal solutions and vice versa.

In the light of this study, there is currently lack of literature that provided an insight into MCDM for residential base camp location selection for companies when considering suitable location or any other business purposes in the OML 58, Niger Delta, and Nigeria. Therefore, the study makes significant contribution to decision making for a base camp location selection in Nigeria oil and gas sector.

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Competing Interest

The author declares that this study is self-funded and he has no personal relationship(s) that may have inappropriately influenced him in writing this article.

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