Multi-Criteria Decision Analysis Towards the Selection of a Perfect Location for Establishing Crude Oil Refinery in Niger Delta Nigeria

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Abstract - Crude oil refinery is a significant manufacturing company in Nigeria, which when properly built in a good location, it will help to stabilize the economic instability in the country. As the end product of the crude oil process is used for different purposes such as, transportation, cooking, electricity generation and for industrial application, which will help to improve the daily living of the Nigerians. This work presents a multi-criteria analysis method for suitable selection of the refinery location in Niger Delta, Nigeria. The suggested location principle takes into consideration the technical aspect of the Environment. The four interest considered in this work are economy factor, nearness to other felicities, environment impact and traffic impact. These interest were examined for three locations alternative such as Delta state, Bayelsa state and Akwa-ibom state using Analytical Hierarchy Process (AHP) to assign weight through pair-wise comparison and Multi-criteria decision-making tool to make a suitable selection. The analytical results show that Akwa-ibom state has the highest aggregative value of the rated score of 539, Delta state of 482 and Bayelsa state of 438. The result derived from this study as proven that AHP method for selection decision making is reasonable and obtainable for refinery selection location.

Keywords: Multi-criteria decision analysis (MCDA); Analytical Hierarch Process (AHP); Refinery in Nigeria; Selection criteria system

1 Introduction

Multi-criteria decision analysis is a basic leadership strategy, which are part of operations research model, that is reasonable for attending to complex issues including high vulnerability, clashing goals, diverse types of information and data, multi interest’s viewpoints, biophysical and financial frameworks [1]. This significant class of strategies is additionally isolated into Multi-target basic leadership and Multi-trait basic leadership. These strategies share the regular qualities of contention among criteria, incommensurable units and challenges in structure/choice of choices.

The primary refinement between the two gatherings of strategies depends on the quantity of choices under assessment. Multi-quality basic leadership strategies are proposed for choosing discrete choices while Multi-target basic leadership techniques are progressively satisfactory to manage multi-target arranging issues, when a hypothetically unbounded number of ceaseless choices are characterized by a lot of imperatives on a vector of choice factors [2– 4]. In Multi-target basic leadership (otherwise called multi target programming or a vector advancement/expansion/minimization issue), the choices are not foreordained but rather a lot of target capacities are enhanced subject to a lot of limitations. The most attractive and effective arrangement is looked for. In this distinguished productive arrangement, it is beyond the realm of
imagination to expect to enhance the execution of any goal without corrupting the execution of something like one other target. In Multi-property basic leadership few options are to be assessed against a lot of characteristics which are regularly difficult to measure [5-7]. There are significantly six stages in the basic leadership process and four noteworthy strides in the working guideline while applying MCDA to settled issues.

Refining in Nigeria started 10 years after oil was found in the oil-rich Niger Delta area during the 1950s. At first beginning in 1965 with a refining limit of 38,000 barrels for each day (bpd), Nigeria's refining limit has become throughout the years and is considered the fourth biggest in Africa. The nameplate limit of 445,000 bpd is housed by 4 refineries deliberately situated in different states around the nation: Rivers, Delta and Kaduna. In spite of having a nameplate limit that should take care of local demand, Nigeria still imports over 80% of refined items to meet its present needs. In contrast to the creation of unrefined, the generation of refined items has been imperfect and Nigeria has reliably attempted to keep its refineries working ideally. The standpoint for refining has been spoiled with vulnerability because of the unfriendly impacts of appropriations, poor upkeep, general operational disappointment and Nigeria is the second biggest maker of oil in Africa, creating over 1.5 million bpd (as at January 2017). With demonstrated unrefined petroleum hold appraisals of around 37 billion barrels as at 2015, Nigeria brags of about 29% of the landmass' rough saves (second in Africa). Yet, Nigeria devour more than what the nation deliver [8].

The need while researchers carrying out several works using MCDA is to see the possible ways to resolve some engineering problems in other to improve the economic situation which in return will lead to achieving the sustainable development goals [14-19]. Several researchers as applied this technique to different aspect of engineering applications such as Ohunakin, and Saracoglu, [21]. Applied five different types of the MCDA method in selecting a perfect location for the installation of a Solar Power Plants in Nigeria for electricity generation. Mayaki et al., [22] Also work on the selection location of a suitable state for developing wind farm for generation of power to meet the demand of electricity supply in Nigeria.

Linkov and Moberg, [23] said that MCDA is an organized way to deal with basic decision making that quantitatively assesses choices, for different situation, measurements, in view of defined venture criteria, master suppositions, and partner inclinations. According to Wood et al., [24], the combination of a wide collection of data to assess project choices and rank them dependent on their incentive concerning a lot of criteria. Is basically encompasses of four phases. The task, major plan and partner feelings, must be define: (1) the arrangement of feasible choices to be assessed and positioned; (2) the criteria of the esteem tree that will influence the choice formulation; (3) the significance of every model in respect to the others or their "weight" trailed by a standardization of loads performed independently for each request of (criteria of request one, criteria of request two (or sub-criteria), and so forth; and (4) the estimation of every option concerning every example, contingent upon the specific MCDA strategy, (3) and (4) may likewise incorporate vulnerability measures.

This result to continues research by researchers in Nigeria on different ways to improve our refinery efficiency and to also develop more refinery in Nigeria. From the statistical analysis of the Nigeria data on the end product of the refinery, which shows that the rate of consumption of
the end product of refinery in Nigeria is on the high side, and when the consumption rate is more
than the production rate the country is in trouble. Therefore, the need to use MCDA comes into
play, which is the focus of this research, to use MCDA to select a suitable state for development
of new refinery among the Niger Delta State in Nigeria to enable the country meets the demand of
the consumer.

2 Methodology
2.1 Data Collection and the Criteria for the Selection Process
The investigation utilized a quantitative strategy for examination through concentrated optional
information social affair, resemblance and handling. The required optional information was
distinguished and acquired from Annual NNPC and different productions of applicable
establishments, for example, Central Bank of Nigeria and OPEC. The total information on
generally speaking yearly oil use in the three chosen states from 2008 to 2017 were acquired.
Professionals ideal and questioner was additionally used to obtained the data and the rating
decisions.

In this research the criteria for appropriate selection process for the three alternatives such as Delta
state (DS), Bayelsa state (BS) and Akwa-ibom state (AS) is based on the sub-interest ratings and
the weighted values of the interest, the interest considered in this study are economy value,
environmental impact, nearness to other facilities, traffic impact, and the ratings are determined
using pair wise comparison matrix by applying the ordinary scale of five (5) point. For example, the five-point scale are: 5 = excellent; 4 = very good; 3 =
good; 2 = satisfactory; 1 = poor. This section explains the process used for the decision making,
such as, analytical Hierarch Process (AHP), building selection criteria system and consistency
analysis for analytical hierarchy process (AHP).

2.2 Method Descriptions of the Analytical Hierarch Process (AHP)
Three standards utilized in the AHP for critical thinking are as per the following: (1) breakdown:
organizing the components of the issue into a chain of command, (2) comparative decisions:
creating a grid of pairwise correlations of all components in a dimension regarding each correlated
component in the dimension quick above it where the central right eigenvector of the framework
gives proportion scaled need evaluations to the arrangement of components looked at, and (3)
amalgamation of priorities: figuring the worldwide need of the components at the least dimension
of the pecking order (i.e., the choices). Breakdown into a pecking order depends on past
investigations and observational encounters. AHP requests that, the issue be organized by the
members in the basic leadership process, in spite of the fact that it isn't fundamental that all
members in the arranging procedure concur on each segment of the issue. Also, it is imperative
that every fundamental component pertinent to the issue are secured inside the progressive system
structure. In its most run of the mill frame, a progressive system is all the time organized from the
best (goals from the administrative outlook) through the quick dimension (criteria and sub criteria
that ensuing dimensions rely upon), and on to the least dimension (which is typically a rundown
of options) Comparative decisions by pairwise examination: Once a pecking order has been
created, one moves to information accumulation, along these lines having the combine shrewd
correlations expected to decide the overall significance of the components in each dimension. The
leaders start the prioritization strategy to decide the overall significance of the components in each
dimension. The criteria and sub-criteria are not similarly vital to the choice at each dimension of
the chain of command, and every elective rate diversely on every standard. AHP can give an
explanatory procedure that can join and unite the assessments of the options and criteria by either an individual or gathering associated with the basic leadership errand [10]. The correlation of two components, that is pairwise examination in AHP, extraordinarily decreases the reasonable multifaceted nature of an investigation. This simplification includes presumptions that considered as sensible by Satty and others [11-13]. Given a pairwise examination, the investigation includes three assignments: (1) building up a correlation network at each dimension of the pecking order beginning from the second dimension and waged down, (2) processing the relative loads for every component of the progressive system, and (3) assessing the consistency proportion to check the consistency of the judgment. Components in each dimension are contrasted in sets with deference with their significance to a component in the following more elevated amount. Beginning at the highest point of the chain of command and working down, the match savvy correlations at a given dimension can be diminished to various square frameworks \( B = [b_{ij}]_{n \times n} \) as in the following equation:

\[
\begin{bmatrix}
    b_{11} & b_{12} & \ldots & b_{1n} \\
    b_{21} & b_{22} & \ldots & b_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    b_{n1} & b_{n2} & \ldots & b_{nn}
\end{bmatrix} = \begin{bmatrix}
    b_{11} & b_{12} & \ldots & b_{1n} \\
    1/b_{12} & b_{22} & \ldots & b_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    1/b_{nn} & 1/b_{2n} & \ldots & b_{nn}
\end{bmatrix}
\]

Therefore, the reciprocal properties are shown in equation (2)

\[
b_{ji} = \frac{1}{b_{ij}}
\]

The method of AHP, is a ruler of relative significance from 1 - 9 for creating individual pair-wise contrasts as shown in Table 1. The weighted vector parameter, \( \omega = [\omega_1, \omega_2, \ldots, \omega_9] \) is calculated from Satty's eigenvector technique [14], when the complete pair wise contrasts matrices are designed, then the calculation of the weights comprises of two steps. First, the normalization of the pairwise matrix, \( B = [b_{ij}]_{n \times n} \), by Eq. (3), and then secondly the weights are calculated by employing Eq. (4). Carrying out the Normalization the following equation below are employed

\[
b_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}}
\]

The weight computation is determining as follows

\[
\omega_{ij} = \frac{\sum_{j=1}^{n} b_{ij}}{n}
\]

Assuming for all that \( i \) and \( j = 1, 2, 3, \ldots, n \).

Equation (5) express the correlation between the weighted vector values, \( \omega \), and the pairwise contrast matrix \( b \) withdrawals.

\[
B \ast \omega = \lambda_{\text{max}} \ast \omega
\]

The \( \lambda_{\text{max}} \) value is an imperative authenticating factors in AHP is employed as a situation index to monitor data through computing the consistency ratio (CR) of the projected vector. To estimate the CR, the consistency index (CI) for all the expression of order \( n \) is gotten from Eq. (6).

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

Therefore, CR is determined by applying equation (5)
\[ CR = \frac{CI}{RI} \]  \hspace{1cm} (7)

Knowing that RI is equal to random consistency index attained from a randomly produced pairwise contrast matrix. Table 3 presented the worth of the RI matrices from the 1 to 10 order. If \( CR \geq 0.1 \), the assessments are acknowledged to be satisfactory. However, \( CR \leq 0.1 \), this will depict that the values of the ratio are unpredictable decisions.

### 2.3 Building selection criteria system for Analytical Hierarchy Process (AHP)

The selection of criteria is important for the valuation process and it has been acknowledged with a comprehensive literature in the introduction. Since the goals, interests, and alternatives has been identified, this paper focused on four types of interests including Economy (B1), Environmental impact (B2), Nearness to other facilities (B3), Traffic impact (B4), and the three alternatives state selected are Delta state (DS), Bayelsa state (BS) and Akwa-ibom state (AS) were high percentage of crude oil which is the raw materials that will be refine is found. Fig. 1. Shows the decision framework of AHP, and the detail descriptions of the assessment criteria are presented in Table 1.

![Fig. 1: Evaluation criteria of the decision framework of the goals, interests, sub-interest and alternatives for the application of Analytical Hierarchy Process (AHP)](image)

| Sub-criteria | Sub-interest | Descriptions |
|--------------|--------------|--------------|
| No           | Sub-interest | Descriptions |
| B11          | Cost         | Cost during manufacturing, running and transportation process, this can be influence state by state. |
| B12          | Profit       | The rate of returns after the manufacturing process and during operations. |
B21 Ecological challenges Effects of the minerals deposit on the environment, which lead to ecological pollution, such as water pollution and land pollution effect on crops growing.

B22 Availability of raw water Preferable a close water source like river or sea

B31 Availability of land That is enough land scape for the constructions and parking space for container and cars. This availability of land is not about the total land scape of the state, but according to free land available for this project.

B32 Availability of power The electrical power for operating the refinery during installations and operations

B41 Transportation facility The possible means of solving the transportation problem of the refine product to outside the state were the refinery is located

B42 Resources, Laborers, Effluent disposal The state that has the highest crude oil, good and hardworking people and method of disposing the effluent

2.4 Consistency Analysis for Analytical Hierarchy Process (AHP)

Consistency examination involves the computing of the Consistency Ratio (CR) and Consistency Index (CI): whereas the Random Index has been developed by Satty, [14] as shown in Table 2, Table 3, shows the relative importance scale to generate the pair-wise comparison matrix.

Table 2: Random inconsistency indices for n ranging from 1 to 10

| N  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI | 0.00| 0.00| 0.58| 0.9 | 1.12| 1.24| 1.32| 1.41| 1.46| 1.49|

Table 3: Relative importance scale Satty, (1994)

| Strength of Relative Importance | Explanations                         |
|---------------------------------|--------------------------------------|
| 1                               | Equivalent significance              |
| 3                               | Moderate significance                |
| 5                               | Strong significance                  |
| 7                               | Very strong significance             |
| 9                               | Extreme significance                 |
| 2, 4, 6, 8                      | Intermediate values of the significance |
| 1/3, 1/5, 1/7, 1/9              | Reciprocal for inverse comparison    |

3 Result and Discussion

In other to determine the pair wise comparison matrix (PWCM), the interest is rated according to the relative scale of from extreme importance to equal importance. In other to determine the normalized pair wise matrix, the total sum of the PWCM in column is used to divide each
individual interest and the average weight of the pair wise matrix is determined using the equation (4) above, as shown in Table 4 to 6.

Table 4: Pair Wise Comparison Matrix

| Interest | B1 | B2 | B3 | B4 |
|----------|----|----|----|----|
| B1       | 1  | 5  | 4  | 7  |
| B2       | 0.2| 1  | 0.5| 3  |
| B3       | 0.25| 2 | 1  | 3  |
| B4       | 0.14| 0.33| 0.3| 1  |

Table 5: Column Total For Pair Wise Comparison Matrix (PWCM)

| Interest | B1 | B2 | B3 | B4 |
|----------|----|----|----|----|
| B1       | 1  | 5  | 4  | 7  |
| B2       | 0.2| 1  | 0.5| 3  |
| B3       | 0.25| 2 | 1  | 3  |
| B4       | 0.14| 0.33| 0.3| 1  |
| Total    | 1.59| 8.33| 5.83| 14|

Table 6: Normalization of the Pair Wise Comparison Matrix (PWCM)

| Interest | B1              | B2              | B3              | B4              |
|----------|-----------------|-----------------|-----------------|-----------------|
| B1       | 0.628930818     | 0.600240096     | 0.686106346     | 0.5             |
| B2       | 0.125786164     | 0.120048019     | 0.056603774     | 0.214285714     |
| B3       | 0.157232704     | 0.360144058     | 0.171526587     | 0.214285714     |
| B4       | 0.088050314     | 0.039615846     | 0.056603774     | 0.071428571     |

To determine the Consistency Analysis of the PWCM, using the equation (6), (7) and (8). The result is shown in Table 7 and Table 8 present the weight of the four interest chosen for this selection process.

\[
\lambda_{max} = \frac{\sum_{j=1}^{n} \omega_{ij}}{n} \quad (8)
\]

Table 7: The detail result of the consistency analysis for the pair wise comparison matrix (PWCM)

| Interest | B1     | B2     | B3     | B4     | Weight sum value | Criterial weight | Consistency Measure |
|----------|--------|--------|--------|--------|------------------|------------------|---------------------|
| B1       | 0.6038 | 0.6459 | 0.9032 | 0.4475 | 2.6004           | 0.6038           | 4.3067              |
| B2       | 0.1207 | 0.1291 | 0.1129 | 0.1918 | 0.5546           | 0.1292           | 4.2933              |
| B3       | 0.1509 | 0.2583 | 0.2257 | 0.1918 | 0.8269           | 0.2258           | 3.6621              |
| B4       | 0.0845 | 0.0426 | 0.0677 | 0.0639 | 0.2588           | 0.0639           | 4.0489              |

\[
\lambda_{max} = 4.0777
\]
\[
C.I = 0.0259
\]
Table 8: interest weight from AHP analysis

| Interest     | B1          | B2          | B3          | B4          |
|--------------|-------------|-------------|-------------|-------------|
| weight       | 0.603819    | 0.129181    | 0.225797    | 0.063925    |

3.1 Decision for selection of the best location for the installation of the crude oil refinery

The decision matrix is formed by the application of the interest weight gotten from the pair wise comparison matrix converted into percentage in order to determine the sub-interest weight, for a quality rating on the alternative, the sub-interest is used to rate the process by applying the ordinary scale of five (5) point. For example, a five-point scale are: 5 = excellent; 4 = very good; 3 = good; 2 = satisfactory; 1 = poor. As shown in Table 9.

Table 9: The rating of the alternatives base on the satisfaction of the sub-interest.

| Sub-interest                                      | Delta state (DS) | Bayelsa state (BS) | Akwa-ibom state (AS) |
|---------------------------------------------------|------------------|--------------------|----------------------|
| Availability of land                              | 3                | 2                  | 5                    |
| Availability of power                             | 4                | 5                  | 3                    |
| Ecological challenges                             | 2                | 1                  | 4                    |
| Availability of raw water                         | 5                | 5                  | 3                    |
| Transportation facility                           | 3                | 2                  | 5                    |
| Resources, Laborers, Effluent disposal             | 4                | 3                  | 4                    |
| Cost                                               | 4                | 5                  | 3                    |
| Profit                                            | 3                | 2                  | 4                    |

Weight decision makers Interests: applies a ranking pattern from highly important to least important using a grading score from 100 to 0. Table 10 show the assign weight ranking done by the decision makers and the weight interest determined by the PWCM. Table 11 shows the result of the weight ranking for the sub-interest for the AHP. Table 12, gives the total result for the three alternative chosen for this MCDA using the method of AHP to rate and rank the three state such as Delta state, Bayelsa state and Akwa-ibom state.

Table 10: Decision makers weight ranking on the interest

| Interest                                 | Important     | Ranking | Weight |
|------------------------------------------|---------------|---------|--------|
| Nearness to other facilities             | So-so important | 2       | 22     |
| Environmental impact                     | Moderately important | 3       | 12     |
| Traffic impact                           | Important      | 4       | 6      |
| Economy                                  | Very important | 1       | 60     |

Table 11: Ranking the sub-interest using the interest weight ranking

| Interest to other facilities | Weight | Sub-interest          | Weight |
|------------------------------|--------|-----------------------|--------|
| Availability of land         | 20     | Availability of power  | 15     |
Table 12: The result score of the three alternatives for the best selection process

| Sub-interest                                  | Weight | Rating | Score |
|-----------------------------------------------|--------|--------|-------|
|                                              |        | DS | BS | AS | DS | BS | AS |
| Availability of land                         | 20     | 3  | 2  | 5  | 60 | 40 | 100 |
| Availability of power                        | 15     | 4  | 5  | 3  | 60 | 75 | 45 |
| Ecological challenges                        | 10     | 2  | 1  | 4  | 20 | 10 | 40 |
| Availability of raw water                    | 8      | 5  | 5  | 3  | 40 | 40 | 24 |
| Transportation facility                      | 4      | 3  | 2  | 5  | 12 | 8  | 20 |
| Resources, Laborers, Effluent disposal       | 5      | 4  | 3  | 4  | 20 | 15 | 20 |
| Cost                                          | 30     | 4  | 5  | 3  | 120| 150| 90 |
| Profit                                        | 50     | 3  | 2  | 4  | 150| 100| 200|
| Total                                         | 482    | 438 | 539 |

Fig. 2: The percentage of the sub-interest weight on the interest and the alternatives
Fig. 3: MCDA result for the three alternative

Fig. 2, shows the rating or the ranking weight done by the expert opinions, and stakeholder preferences on the sub-interest weight for the AHP method, this shows that for any driving profit organization, a lot of considerations are made on cost of building the project and the returned field back in term of what do they stand to benefit from the project. From Fig. 2, the economy factor in terms of cost and profit has the highest percentage of 21% and 35%, availability of land 14%, power availability 11%, ecological challenges 7%, availability of raw water of 6%, transportation facility and resources are 3% each. Fig. 3, shows the AHP result for the three alternative, the most selected state for the building of the Nigeria refinery is Akwa-ibom state with a total weight of 539. This could be as a result of less industrial area around the Akwa-ibom state which give rise to the state having more advantage than the other two state due to more availability of land. Also from detail result of the consistency analysis for the pair wise comparison matrix (PWCM) shown in Table 7, proofs that the AHP approach used for this study is satisfactory and is in line with the observation reported by Jesuleye et al., [5] and Do and Kim [10], in their study on optimal MCDM selection process on refinery products and concrete repairs.

4 Conclusion
Nigeria has a great potential for crude oil production and this should be considered to solve the issue of inadequate of petroleum product, which has led to inflation of the price of project develop, due to the process of importation and exportation of the crude oil product from within and out of the nation. The AHP used is a suitable method from MCDA, for selection of the suitable location for more refinery in Niger Delta state in Nigeria. From literatures the three alternatives are among the Niger Delta state with good and reasonable amount of crude oil as a natural resource. Therefore, the application of AHP was employed to generate a normalized column total matrix which is approximately one (1), consistency index of 0.0259 and consistency ratio of 0.0288 which is within the expected range for selection of suitable location, and finally from the MCDA, Akwa-ibom state
was found to have the highest weighted values, that means the selected area were the refinery should be located in Akwa-ibom state.

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