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Analytic Hierarchy Process–GIS Based Decision Support System for Modular Petroleum Refining Plant Siting: A Case of Edo State, Nigeria

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ABSTRACT

Nigeria - an oil rich country, despite having a nameplate petroleum refining that exceeds demand ranks as the 3rd highest importer of petroleum products in Africa, importing over 80% of products consumed due to its capability to keep its petroleum refineries functioning optimally over the last four decades. This has led to a lively debate on the need for modular refineries as a quick fix to the shortages rather than continue to import at a very high cost to the nation. Constructing a modular refining plant is a major long-term investment that requires a comprehensive evaluation to identify the best available location that can simultaneously meet the requirements of regulations and minimize economic, environmental, health, and social cost. This study aimed at identifying suitable areas for possible locations of modular refineries in Edo State using an integrated approach of Geographical Information System (GIS) (which was used in building a geo-spatial workflow) and Analytic Hierarchy Process (AHP) of Multi-Criteria Decision Analysis (MCDA) (for criteria weight determination). Fifteen (15) key environmental criteria, based on a review of pieces of literature, specifications, and Environmental Impact Assessment Act (EIA) on the siting of petroleum refining plants were selected for this study (namely: Water bodies, Electricity transmission line Land use/Land cover, Topography, Sensitive and Protected areas, Critically Polluted areas, Existing Industrial areas, Transportation network, Flood zones, Source of crude oil, Wind speed, Large-scale Mines, Population density, Proximity to major settlement and Ground Water level) based on reviewed works of literature to be applicable to this study. The result of this analysis, showed that 20.391km^2, representing 0.36% of the total available land Area which is concentrated majorly within the south-east zone of the study area was unsuitable; 212.669km^2 representing 3.78% within the northern region of the study area were least suitable; 2943.584km^2 representing 52.29%, located in the central and north-east regions of the study area were moderately suitable; 2266.082km^2 representing 40.25% which fell within the south-south and south-west regions of Edo State (the study area) were found to be more suitable while 186.082km^2 representing 3.32% located in the south-south region of the study area (Edo state) was most suitable. The research method and results of this work can be used as a spatial decision a support tool for optimum sites selection and sustainable spatial planning and development.

Key words: GIS, MCDA, AHP, Site Selection, Edo State, Criteria, Petroleum

1. INTRODUCTION

Modular Petroleum refineries (plants), from simple diesel production units to more sophisticated cracking refineries are increasingly becoming a flexible and cost-effective supply option for crude producers in remote regions. This is particularly where there is a need to adapt rapidly to meet local demand. Relatively low capital cost, speed, and ease of construction are key advantages of a modular mini-refinery. These modular refining plants will not only help meet the growing demand for fuel but will go a long way to help boost the economic base and create high pay employment opportunities for both skilled and lower-skilled workers, strengthening the community socially and economically.

The Nigerian Department of Petroleum Resources [1] while listing the key benefits of establishing modular refineries across the country - Nigeria, added, that the construction of modular refining plant will help promote the availability of petroleum products in the country, conserve foreign exchange utilization for the importation of Petroleum Products, promote socio-economic development in order to stop restiveness, criminal and illegal refinery activities, thereby sustaining peaceful coexistence in the Niger Delta region and mitigate and eliminate environmental degradation associated with illegal refinery activities, crude oil theft, and pipelines vandalism. Despite this monumental projected importance of modular petroleum plants in remedying unemployment and economic issues, the adverse impact of these modular refineries on their immediate environment and beyond cannot be underemphasized. Therefore, the siting of these types of industries becomes an issue of major concern.

The identification of a suitable site for industrial development is increasingly becoming a problem faced by both national and international investors [2-3], there are no operational measures of critical factors affecting such locations in the study area. Consequently, determining the best sites among alternatives are the key challenges that stockholders must face. In industrial site selection processes, final decisions are based on the evaluation of a number of alternatives criteria [4-5]. An effective technique that can integrate geographical data with value judgments to support decision-making processes is therefore necessary. Among the geo-information techniques with widely recognized capabilities that are used for evaluation of suitability factors and allocation of various measures of suitability to specific sites is GIS combined with MCDA [6-7]. To effectively analyze complex tradeoffs involving multiple criteria, GIS can perform deterministic buffers, overlays, and other geoprocessing operations, while multiple criteria procedures can be used to evaluate alternatives based on value judgments [8-9]. This ideally has led to the frequent application of GIS-MCDA in the identification of suitable areas for land development currently [10-12] which effectively reduces engineering costs and minimizes adverse impacts to the environment. GIS-MCDA technology is fully integrated and widely accepted for assisting government agencies to manage programs that support decision-makers and protect the environment. The aim of this research is to apply GIS-MCDA techniques in selecting suitable sites to locate modular refining plants in Edo State, Nigeria.

2. MATERIALS AND METHOD

2.1 Study Area

The study area, Edo state is in the South-South geopolitical zones of Nigeria. Edo is a state in the southern part of Nigeria. It was created on 27th August 1991 when the former Bendel State (now Edo and Delta) was separated into these two states. Edo state is located between latitudes 7°18'8.61"N to 5°52'48.77"N of the equator and longitudes 6°36'59.29"E to 5°12'58.38"E of the Greenwich meridian, with a surface area of approximately 19,603 km^2. Its capital is Benin City. With a population of 3,218,332 million people. It is bounded in the north and east by Kogi State, in the south by Delta State and in the west by Ondo State. Economically, Edo state is more of a commercial and agricultural driven state. The majority of its population are either farmers or traders. There are various solid mineral deposits within the state such as; industrial clay, silica, lignite, kaolin, tar sand, decorative rocks, limestone, etc. still waiting to be properly used to their full potential. Edo state also has a deposit of crude oil (though, not as much as Delta state) and this makes it one of the petroleum-producing states in Nigeria. Figure 1 is the map of Nigeria showing the Study Area – Edo state.

The methodology involved using an integration of GIS and AHP method of Multi-Criteria evaluation. The following step/procedure was followed**:**

i. Criteria Selection and Data Acquisition
ii. GIS Spatial and Attribute Database Creation and Modeling
iii. Derivation of Datasets
iv. Reclassification and Standardization of Datasets
v. Determining the relative weights (Using AHP Pairwise Comparison Matrix Approach)
vi. Dataset overlay (WLC Approach)
vii. Selecting the Suitable Sites
viii. Validation of Results

2.2 Criteria Selection and Data Acquisition

Based on reviewed pieces of literature and guidelines from relevant authorities, in this case, Department of Petroleum Resources (DPR), Nigerian National Petroleum Company, and Environmental Impact Assessment (EIA) Act on the siting of petroleum refining plants, the following fifteen (15) criteria (factors/constraints) shown and explained in table 1 were considered for this research. Data relevant to this research were identified and assembled based on the selected criteria. These data include; Google earth satellite imagery (2018, 100m resolution), water table level data, shapefiles of protected areas, wind speed data, Shuttle Radar Topographic Mission (SRTM), point data of existing large-scale mines, critically polluted areas, and population density data. From these data, other datasets were extracted. Some of these datasets include; Land use/Land cover, Slope (from SRTM), Roads and Water bodies and Major Settlement (from satellite imagery), etc.

All spatial and attribute data gathered (through direct and indirect methods) were used in creating the GIS attribute database and then linked to the spatial database using the Database Management System module of the GIS environment.

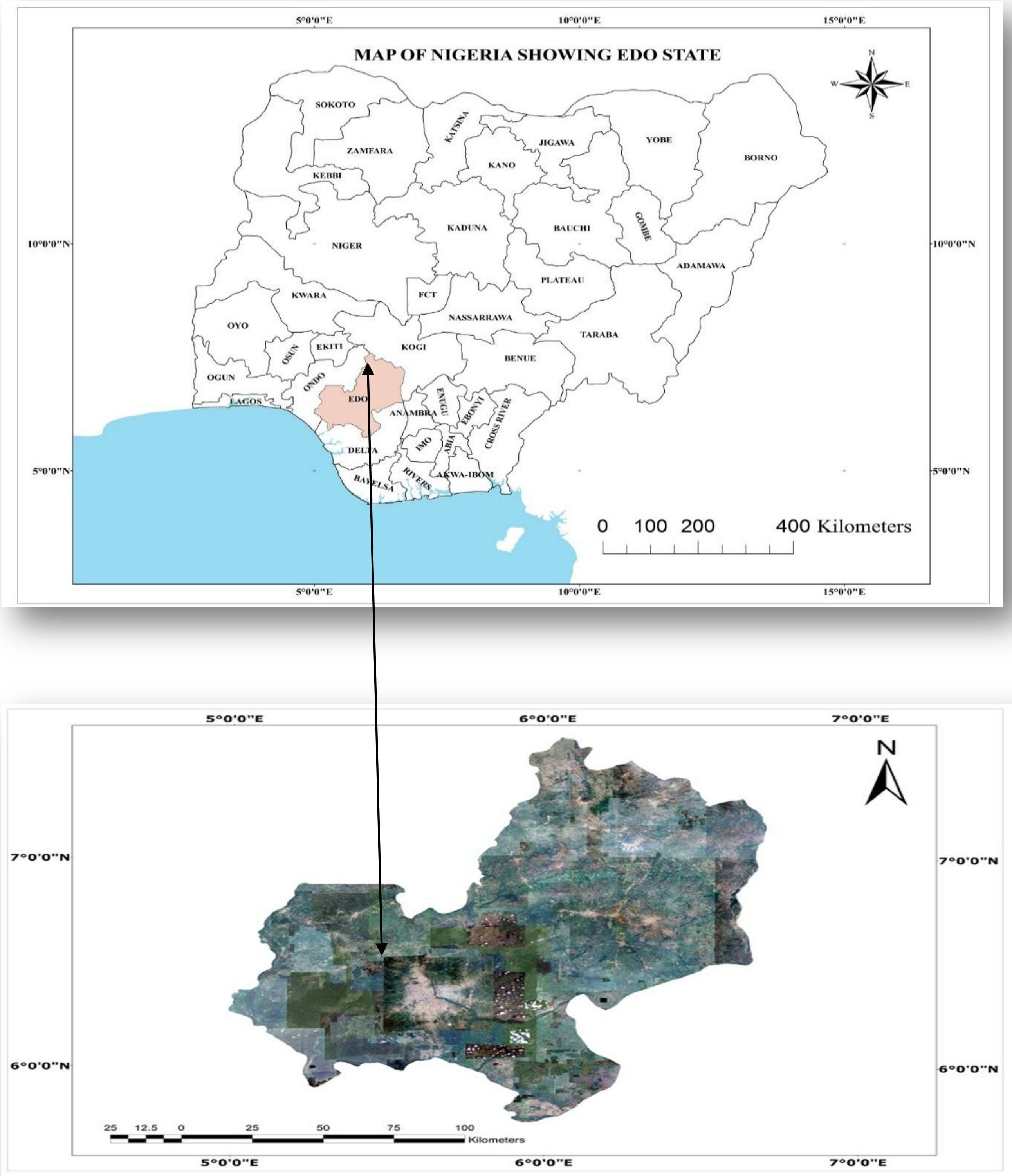

Fig. 1 Map of Nigeria indicating the study area (Edo state) and the satellite image of Edo state

2.3 Derivation of Datasets

Datasets were derived from the various raw data acquired by creating a model using the Model Builder of ArcGIS (which is used for building geoprocessing workflows). Created Datasets include slope, distance to road, distance to rivers, distance to flood zones, etc. as shown in the structural flow diagram of the suitability model. Other datasets which include the distance from areas avoided (protected areas, forest, existing waste dumps sites etc.) were derived using the

Euclidean distance analysis tool. Point data e.g. water table level was converted to raster using the Kriging interpolation method. In the process of deriving these various datasets, all the input data were defined as model parameters.

2.4 Reclassification/Standardization of Datasets

The datasets were standardized to a common measurement system that represents a relative weighting scale that permits analysis to be completed logically between the datasets and shows the suitability level for each of the standardized criteria. For this research, all the datasets were reclassified into nine classes: with (1) representing the least suitable and (9) the most suitable areas. The initially derived dataset values categorized into ranges will be floating and continuous in nature and will need to be reclassified so that each range of values can be assigned one the discrete integer value of 1-9 according to the measurement scale. This is because the inputs of the weighted overlay, which will be used in the next step, must contain discrete integer values.

2.4.1 Ranking and Determination of Relative Weights

Here, the pairwise comparison method of AHP developed by Saaty [13], for determining and allocating weights was applied. The pairwise comparison approach uses a ratio matrix is known as the Eigenvector method to compare one criterion with another. Additionally, it uses a numerical scale with values ranging from 1 to 9, where 1 means that the two factors are equally important and 9 means that one factor is absolutely more important than the other as shown in Table 1. If a factor is less important than another then this is indicated by reciprocals of the 1 to 9 values (i.e.1/2 to 1/9). Table 2 below is the Pairwise Comparison Matrix formed.

Table -1 Judgment Values and Their Interpretations [13]

Judgment value	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderately importance	Experience and judgment slightly favour activity over another
5	Strongly Importance	Experience and judgment strongly favour activity over another
7	Very strongly important	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extremely important	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6 and 8	Intermediate values between adjacent judgments.	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

2.5 Determining the relative weights (Using AHP Pairwise Comparison Matrix Approach)

The Analytical Hierarchy Process (AHP) was used to determine the relative weights of criteria using the Pairwise comparisons of the criteria (factors/constraints) to create a ratio matrix by taking the numerical comparison outcome values as input and producing relative weights as output. Generally, three (3) steps are involved as follows:

(i) Comparison of Factors/Constraints
(ii) Formation of Pairwise Comparison Matrix
(iii) Computation of the weights of Criteria: this involves two (2) steps as follows:
(a) Formation of Normalized Pairwise Comparison Matrix; and
(b) Formation of the Prioritization weight matrix.
(iv) Calculation of Consistency Ratio (CR) to check for any bias in the judgment values in Table 2.

Table -2 Pair-wise Comparison Matrix of the study

	MWB	**ETL**	**LULC**	**TOPO**	**SPA**	**CPA**	**EIA**	**MTN**	**FZ**	**SRM**	**WS**	**LSM**	**PD**	**MS**	**GWL**
MWB	1.00	6.00	0.25	3.00	7.00	5.00	0.25	5.00	7.00	0.33	4.00	6.00	1.00	4.00	1.00
ETL	0.17	1.00	0.11	0.33	1.00	2.00	0.11	0.50	2.00	0.11	0.33	1.00	0.17	0.50	0.17
LULC	4.00	9.00	1.00	6.00	9.00	8.00	1.00	7.00	9.00	1.00	6.00	8.00	3.00	7.00	3.00
TOPO	0.33	3.00	0.17	1.00	3.00	2.00	0.17	1.00	3.00	0.17	1.00	3.00	0.33	2.00	0.33
SPA	0.14	1.00	0.11	0.33	1.00	1.00	0.11	0.25	1.00	0.11	0.25	1.00	0.17	0.50	0.17
CPA	0.20	0.50	0.13	0.50	1.00	1.00	0.11	0.33	1.00	0.11	0.33	1.00	0.20	0.33	0.20
EIA	4.00	9.00	1.00	6.00	9.00	9.00	1.00	6.00	9.00	1.00	6.00	9.00	4.00	6.00	4.00
MTN	0.20	2.00	0.14	1.00	4.00	3.00	0.17	1.00	3.00	0.17	1.00	3.00	0.50	1.00	0.50
FZ	0.14	0.50	0.11	0.33	1.00	1.00	0.11	0.33	1.00	0.11	0.25	1.00	0.20	0.33	0.20
SRM	3.00	9.00	1.00	6.00	9.00	9.00	1.00	6.00	9.00	1.00	5.00	9.00	4.00	6.00	4.00
WS	0.25	3.00	0.17	1.00	4.00	3.00	0.17	1.00	4.00	0.20	1.00	4.00	0.50	1.00	1.00
LSM	0.17	1.00	0.13	0.33	1.00	1.00	0.11	0.33	1.00	0.11	0.25	1.00	0.17	0.25	0.25
PD	1.00	6.00	0.33	3.00	6.00	5.00	0.25	2.00	5.00	0.25	2.00	6.00	1.00	2.00	2.00
MS	0.25	2.00	0.14	0.50	2.00	3.00	0.17	1.00	3.00	0.17	1.00	4.00	0.50	1.00	1.00
GWL	1.00	6.00	0.33	3.00	6.00	5.00	0.25	2.00	5.00	0.25	1.00	4.00	0.50	1.00	1.00
TOTAL	**15.85**	**59.00**	**5.12**	**32.33**	**64.00**	**58.00**	**4.97**	**33.75**	**63.00**	**5.09**	**29.42**	**61.00**	**16.23**	**32.92**	**18.82**

2.5.1 Normalized Pairwise Comparison Matrix Formation

The normalized Pairwise Comparison matrix was formed from the above Pairwise Comparison Matrix. Here, the elements of the normalized matrix were formed by dividing the elements of each column by their sum total. For instance, the first element of the first column of the normalized matrix is computed thus; 1/15.85 = 0.06. Where 1 is the first element of the first column of the pairwise comparison matrix and 15.85 is the sum total of its column as indicated in Table 3.

Table -3 Normalized Pairwise Comparison Matrix

	MWB	**ETL**	**LULC**	**TOPO**	**SPA**	**CPA**	**EIA**	**MTN**	**FZ**	**SRM**	**WS**	**LSM**	**PD**	**MS**	**GWL**
MWB	0.06	0.10	0.05	0.09	0.11	0.09	0.05	0.15	0.11	0.07	0.14	0.10	0.06	0.12	0.05
ETL	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.03	0.02	0.01	0.02	0.01	0.02	0.01
LULC	0.25	0.15	0.20	0.19	0.14	0.14	0.20	0.21	0.14	0.20	0.20	0.13	0.18	0.21	0.16
TOPO	0.02	0.05	0.03	0.03	0.05	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.02	0.06	0.02
SPA	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.01
CPA	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01
EIA	0.25	0.15	0.20	0.19	0.14	0.16	0.20	0.18	0.14	0.20	0.20	0.15	0.25	0.18	0.21
MTN	0.01	0.03	0.03	0.03	0.06	0.05	0.03	0.03	0.05	0.03	0.03	0.05	0.03	0.03	0.03
PFZ	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01
SRM	0.19	0.15	0.20	0.19	0.14	0.16	0.20	0.18	0.14	0.20	0.17	0.15	0.25	0.18	0.21
WS	0.02	0.05	0.03	0.03	0.06	0.05	0.03	0.03	0.06	0.04	0.03	0.07	0.03	0.03	0.05
LSM	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01
PD	0.06	0.10	0.07	0.09	0.09	0.09	0.05	0.06	0.08	0.05	0.07	0.10	0.06	0.06	0.11
PMS	0.02	0.03	0.03	0.02	0.03	0.05	0.03	0.03	0.05	0.03	0.03	0.07	0.03	0.03	0.05
GWL	0.06	0.10	0.07	0.09	0.09	0.09	0.05	0.06	0.08	0.05	0.03	0.07	0.03	0.03	0.05
TOTAL	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

2.5.2 Prioritization weight matrix formation

In computing the elements of this matrix, the normalized sum of each row is divided by the total number of its criteria. The obtained values (average) provides the relative weights of the criteria being compared. For instance, the criteria weight of Major Water Bodies (MWB) in this can be obtained thus;

0.06 + 0.10 + 0.05 + 0.09 + 0.11 + 0.09 + 0.05 + 0.15 + 0.11 + 0.07 + 0.14 + 0.10 + 0.06 + 0.12 + 0.05 (sum of the elements in first row) = 1.35

Total number of criteria in first row = 15

Therefore, the weight of Major Water bodies (MWB) = 1.35/15 = 0.09

Weight of the criteria in percentage = 0.09 x 100 = 9%. The computational output is shown in Table 4.

Table -4 Prioritization Weight Matrix

Criteria Code	**Row total of the Normalized Matrix**	**Average**	**Weight (%)**	**Criteria Name**
MWB	1.35	0.09	9.00	Major WaterBody
ETL	0.26	0.02	2.00	Electricity Transmission Line
LULC	2.70	0.18	18.0	Landuse/Landcover
TOPO	0.54	0.04	4.00	Topography (Slope)
SPA	0.22	0.01	1.00	Sensitive/Protected Areas
CPA	0.22	0.01	1.00	Critically Polluted Areas
EIA	2.79	0.19	19.0	Existing Industrial Areas
MTN	0.53	0.04	4.00	Major Transportation Network
PFZ	0.21	0.01	1.00	Proximity to Flood Zones
SRM	2.70	0.18	18.0	Source of Raw Materials
WS	0.62	0.04	4.00	Wind Speed
LSM	0.22	0.01	1.00	Large Scale Mines
PD	1.14	0.08	8.00	Population Density
PMS	0.53	0.04	4.00	Proximity to Major Settlements
GWL	0.95	0.06	6.00	Groundwater Level
Total	**15.00**	**1.00**	**100.00**	

2.6 Datasets Overlay

Two of the most commonly utilized procedures for multi-criteria evaluation in combining or overlaying datasets are the Weighted Linear Combination and Concordance-Discordance Analysis [14]. Weighted Linear Combination (WLC) was adopted in this study due to the fact that it is widely used and can be easily executed in the GIS environment. A suitability score or index was determined by obtaining the summation of the product of the weight of each criterion with its standard suitability score according to equation (1).

$$SI = \Sigma w_i x_i. \quad (1)$$

Where;
SI = the suitability index,
w*i*= the relative importance (weight) of each criterion
i and x*i* = the standardized score of each criterion *i*.
Hence a suitability map with the constraints was derived from equation (2);

$$S = (\sum_{i=1}^{n} wi \times xi) \times \prod cj \quad (2)$$

With c_j= Boolean value of limited criterion and π is the product of constraint
In the overall result, the higher S value is, the higher the suitability level of area (in this case for locating a modular refining plant).

2.7 Selecting the Suitable Sites

After the determination of the weight in this study, the individually weighted criteria were combined and overlaid to obtain a suitability index scale. The suitability index was then estimated from the suitability values of all the locations in the area under consideration. In this combination approach, it is assumed that the more favorable a factor is, the more desirable the location will be [15]. Thus, the suitability scale was grouped into five main categories:

(i) Unsuitable,
(ii) Least Suitable,
(iii) Moderately Suitable,
(iv) More Suitable and
(v) Most Suitable.

The GIS weighted overlay function was used to perform the calculation based on the above equations. The raster suitability index map was then converted to Vector (using the raster to polygon analysis tool), thus enabling a spatial query and calculation of the Areas of indices (shown in figure 2 below).

3. Results and Discussion

The GIS – AHP approach used in this research resulted in the production of suitability maps based on the criteria used – indicating a map of Potential Suitable Sites for locating a Modular Refinery in the study area. Figure 2 shows the map of Potential Suitable Sites for locating a Modular Refinery while Table 5 shows some of the communities within the various categories of suitability.

Table -5 Communities and their Suitability Levels

Index	Suitability Level	Total Area (km^2)	Some Identified Communities
0	unsuitable	20.391	Izihiri, Ugho and Utonbubu
4	Least suitable	212.669	Oja Sale, Anyara, Ojirami Ogbo, Ososo, Megori, Anyaran, Ineme Osa, Imiekwi, Dagbala, Makeke, Oku, Ogute and Okugbe communities
5	Moderately suitable	2943.584	Ayabo, Ake, Odame, Ewan, Ogada, Iyanomo, Obadan, Okahmavmen, Ogaga, Usomehe, Urhomehen, Egbokor, Owe, Owobamibo and Udochi communities
6	More suitable	2266.082	Urhokuosa, Ikpoba, Igbobi, Egba, Ikoka Etete, Ugboha, Ologbo, Sapoba, Igbobi, Ekose, Idegun, Ugboko, Irokhim, Iloji and Asaboro communities
7	Most suitable	186.829	Ikewa, Ajiko, Ugbo, Evbuarhue Okuku Upekeli, Gbelekegan Ebiotumere and Ugbekele communities

From the suitability index map, it was observed that the most suitable areas (7) are concentrated in the south-south region of the study area (Edo state). The majority of the more suitable (6) areas fell within the south-south and south-west region of Edo State. A larger percentage of the moderately suitable (5) areas were within the Central and North-East regions of the study area. The least suitable (4) areas are in the northern region of the study area and the unsuitable sites (0) were within the south-east zone of the study area. The finding agrees by several studies [3, 6, 14]. The suitable sites, as depicted in figure 2 were selected further away from identified constraints which included settlement areas, sensitive and protected areas, etc. to prevent any social and environmental breaches as well as to establish the economic viability of the project. The result of the final suitability map shows that a land Area reckoned to be 20.391km^2, representing 0.36% of the total available land Area (which excluded areas restricted from any development), was classified as unsuitable; 212.669km^2 of the land area representing 3.78% was classified as least suitable; 2943.584km^2 representing 52.29%, was classified as moderately suitable; while 2266.082km^2 representing 40.25% was classified as more suitable and 186.082km^2 representing 3.32% was classified as most suitable. This result provides vital reference points for discussions about modular refining plant siting (optimum) that would meet the needs of stakeholders and decision-makers. The research method and results of this work can be used as a spatial decision support tool for optimum sites selection and sustainable spatial planning and development It is beneficial not only to explore the best locations identified by the suitability model but also to investigate other suitable candidate sites. Some of the identified sites were visited to validate their suitability. In doing this, a ground truth survey was carried out on the obtained result. This was done to account for conformity of the result on the ground with what is on the suitability map and thereby determining its reliability.

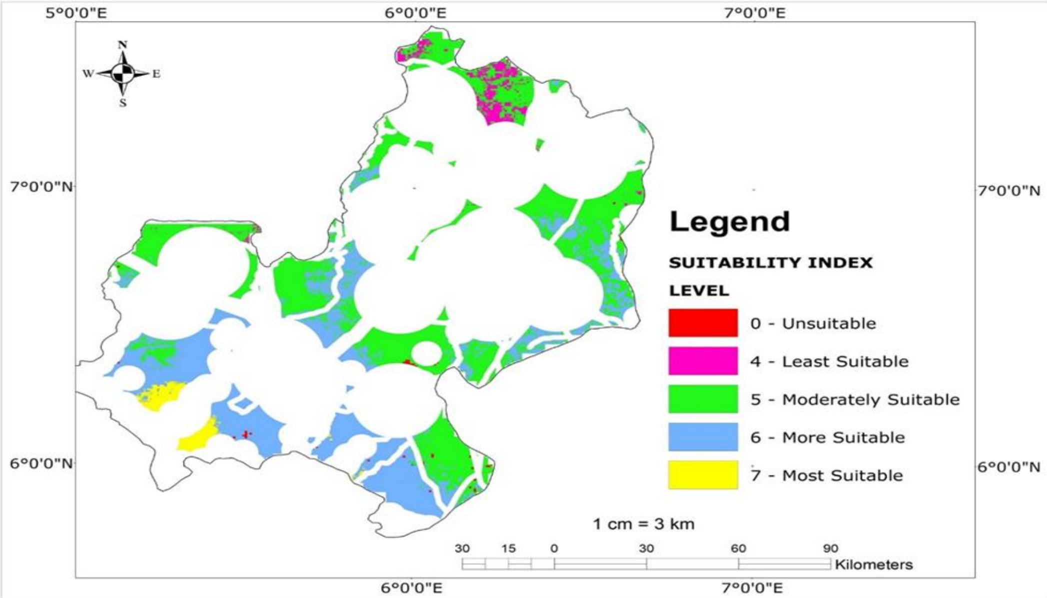

Fig. 2 Map of Potential Suitable Sites for locating a Modular Refinery

4. CONCLUSION

Respect for existing legislation and increased public awareness of environmental issues increasingly makes the selection of suitable locations more complicated. The results of the study have helped proved GIS-AHP to be a veritable Spatial Decision Support System (SDSS), capable of assisting, decision-makers in identifying suitable sites for Modular Refinery. With this, it is expected that sustainable land-use development which ensures the use of land resources in an organized manner that provides maximum socio-economic benefits, and addresses the needs of the present and future generations can be achieved particularly as the government of Nigeria is currently strategizing to reposition Nigeria Oil & Gas industry with top priorities aimed at developing a stable and enabling oil and gas landscape with improved transparency, efficiency, stable investment climate, and a well-protected environment. Finally, It is hopeful that, in the future, stakeholders, such as the government, oil and gas companies/experts, environmental managers, investors and planners, etc. will see the benefit of the GIS-based multi-criteria decision analysis approach in selecting suitable sites for modular refining plant as well as its capability for achieving sustainable land-use development which ensures the use of land resources in an organized manner that provides maximum socio-economic benefits and addresses the needs of the present and future generations.

REFERENCES

[1]. DPR (2017). General Requirements and Guidance Information for the Establishment of Modular Refineries in Nigeria. Retrieved from https://www.dpr.gov.ng/wp Content/uploads/2018/03.

[2]. Ishikawa, T. (2012). A Role of chaotic phenomenon and the central place system in a firm’s location selections. *In Theoretical Economics Letters*, 2, 101-108.

[3]. Badri, M. (2007). Dimensions of Industrial location factors: Review and Exploration. *Journal of business and public affairs*, 1 (2).

[4]. Safian, E. and Nawawi A. (2012). Combining AHP with GIS in the Evaluation of Locational Characteristics Quality for Purpose-built Offices in Malaysia. 6th international Real Estate Research Symposium (IRERS) Selangor, Malaysia.

[5]. Drobne, S. and Lisec A. (2009). Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. *Informatica*, 33, 459–474.

[6]. Al-Hanbali, A., Alsaaideh, B. and Kondoh, A. (2011) Using GIS Based Weighted Linear Combination Analysis and Remote Sensing Techniques to Select Optimum solid Waste disposal Sites Within Mafraq City, Jordan. *Journal of Geographic Information System*, 3, 267-278.

[7]. Soltani, S. R., Mahiny, A. S. and Monavari S. M. (2011). Urban Land use management, based on GIS and Multi criteria Assessment, Case study of Tehran Province, Iran. *International Journal of Environmental Protection*, 1(4), 22-27.

[8]. Khan, D. and Samader S. R. (2014) Municipal solid waste management using Geographical Information System and Aided Method: A Mini Review. *Waste Management and Research*, 32(11), 1049-1062.
[9]. Duc, T. (2006) Using GIS and AHP techniques for land use suitability analysis. Symposium on Geo-informatics for spatial infrastructure development in earth and allied sciences, Vietnam.
[10]. Misra, S. K. and Sharma S. (2015) Site Suitability Analysis for Urban Development: A Review. *International Journal on Recent and innovation Trends in Computing and Communication*, 3(6) 3647- 3651.
[11]. Carver, S. (2007). Integrating Multi-criteria evaluation with Geographical information Systems. *International Journal of geographical information systems.* 5, 321-339.
[12]. Mokarram. M. and Aminzadeh F. (2011). "GIS-Based Multicriteria Land Suitability Evaluation Using Ordered Weight Averaging With Fuzzy Quantifier: A Case Study in Shavur Plain, Iran." The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 38.
[13]. Saaty, T. L., (1980). The Analytic Hierarchy Process. New York: McGraw-Hill.
[14]. Carver, S.J. (1991). Integrating Multi-Criteria Evaluation with Geographical Information Systems. *International journal of Geographical Information System.* 5 (3), 321-339.
[15]. ESRI. (2014). *Learning ArcGIS Spatial Analyst: Working with Operators and Functions*. Retrieved from http://training.esri.com/Courses/LearnSA/index.cfm?c=196 01/06/2015