Application of Hybrid Fuzzy-Topsis for Decision Making in Dam Site Selection

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Abstract

Making the best choice of location for dam sitting can now be addressed better with the concept of Technique for Ordering Preference Similarity to Ideal Solution (TOPSIS) an operational research technique when used with fuzzy logic, an artificial intelligence approach which has really helped in eliminating the vagueness arising from just using TOPSIS alone when several decision makers are involved in the task of making the best choice out of the several alternative choices available. The ArcGis alongside remote sensing tool were used with TOPSIS to select the best site for dam construction. 17 decision makers grouped into 4 teams were involved in the decision making process, 6 criteria were considered and 4 potential dam locations (A, B, C, D) selected from where the best location was chosen. In the end location A was chosen as the best site for the dam construction with closeness to ideal solution of 0.547

Keywords — *TOPSIS, Fuzzy, Dam, MCDA, Remote Sensing, ArcGis*

I. INTRODUCTION

The selection of the best site for a dam is among the decisions that are of particular importance in water supply management, as an optimal selection can improve the security of the water supply of a region and groundwater regeneration. . Hence because of this, the selection of optimal location for dam could lead to significant cost saving. In order to locate the optimal dam site, various studies are necessary Choosing the best site among several alternative sites for the construction of dam when putting certain criteria such as total cost of construction, topography, proximity to the targeted community and accessibility to site and labour can sometimes be a challenge for the structural engineer. Decision-making and planning on issues of such significance cannot be conducted only through the traditional viewpoint of cost-benefit analysis [8] For the location of dam site and construction [7] suggested that a lack of understanding of the complexity of environmental impacts such might have, and also the relationship between biophysical changes and socioeconomic impacts, means that many management problems are, at best, only semi-structured[7]

Multi criteria decision analysis is an approach used in this research work to assist the structural engineer in his decision in locating an optimum site for the purpose of dam construction in. Multi-criteria decision analysis (MCDA) methods have been developed to assist several decision makers in their unique and personal decision process. MCDA methods provide stepping-stones and techniques that help the decision maker in finding a compromise solution. They have the distinction of placing the decision maker at the centre of the process. However they are not automatable methods that always leads to the same solution for every decision maker, but they incorporate subjective information. Subjective information, also known as preference information, is provided by the decision maker, which leads to the compromise [1]. TOPSIS which is one of the various MCDA methods was used in this research work.

With the TOPSIS method an assumption is made that each criterion chosen has a tendency of monotonically increasing or decreasing utility which leads to easily define the positive and the negative ideal solutions. To evaluate the relative closeness of the alternatives to the ideal solution Euclidean distance approach is proposed. A series of comparisons of these relative distances will provide the preference order of the alternatives [2].

II. MCDA DECISION SUPPORT

The decision-making process involved in the design of any civil engineering structures/ systems requires the selection of the most promising choice for the design from a large set of possible alternatives, based on an evaluation using specified criteria reflecting the acceptability of a design [3], Environmental decisions are often complex and multifaceted and involve many different decision makers with different priorities or objectives—presenting exactly the type of problem that behavioural decision research has shown humans are poorly equipped to solve unaided. Several individuals, when confronted with such difficult situations, will try to use intuitive or heuristic approaches to simplify the complexity until the problem seems more manageable. In the process, important information may be lost, opposing points of view may be discarded, and elements of uncertainty may be ignored [5]. Multi-criteria decision analysis (MCDA) methods have been developed to assist several decision makers in their unique and personal decision process. MCDA methods provide stepping-stones and techniques that help the decision maker in finding a compromise solution. They have the distinction of placing the decision maker at the centre of the process [2]. Multi criteria decision analysis (MCDA) not only gives better-supported method for the comparison of project alternatives based on decision matrices but also makes available the ability of being able to provide structured methods for the incorporation of project stakeholders' opinions into the ranking of alternatives [6] Fuzzy systems are useful in two ways they are situations involving highly-complex systems which are not fully understood, secondly, situations where an approximate, but fast, solution is warranted.

The TOPSIS method is based on five computation steps. The first step involves the gathering of information based on the performances of the alternatives on the different criteria. These performances need to be normalized in the second step. The normalized scores are then weighted and the distances to an ideal and anti-ideal point are calculated. Finally, the closeness is given by the ratio of these distances [1].

III. METHODOLOGY

The methods used in this study are based on the integration of the fuzzy logic with TOPSIS together with ArcGis and remote sensing.

A. Determination Of Suitable Criteria

This involves using a comprehensive review of literatures for the selection of different criteria that affects the construction of dam in the study area. Six criteria were selected which includes closeness to the target community, geotechnical condition of each of the selected locations, surface and under water topography of each location, availability of sufficient undeveloped land mass for the construction of other sub structures, cost of construction, accessibility to the site (then materials and labour) during construction. The performance of each of the locations with respect to each of the criteria was measured

B. Selection of Suitable Potential Location

Here the direction of the flow of water for the river was the first criterion considered in choosing the potential alternative locations for the dam site as shown in Fig 1. These provided an accurate insight to flow directions of the river, from where 4 possible dam locations A,B, C and D were selected

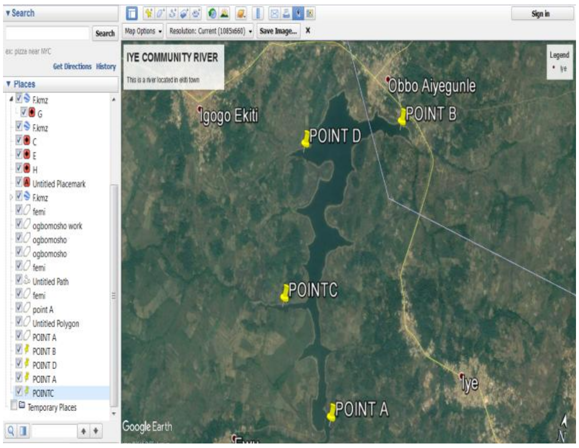

Fig 1 Potential Dam Locations with Flow Direction

C Measuring the Performance Of Each Alternative Relative To The Criteria

Here the performances of each of the alternatives relative to the criteria under consideration were measured. The steps involved in each are highlighted below.

1) Measuring the Closeness Criteria

Here the closeness of each of the alternatives to the targeted location was measured using digital means as provided by the satellite imagery. Their linear average distance from the targeted location were measured using the linear measuring tool provided by the satellite imagery as shown for one of the locations in Fig 2 with the result shown in Table 1

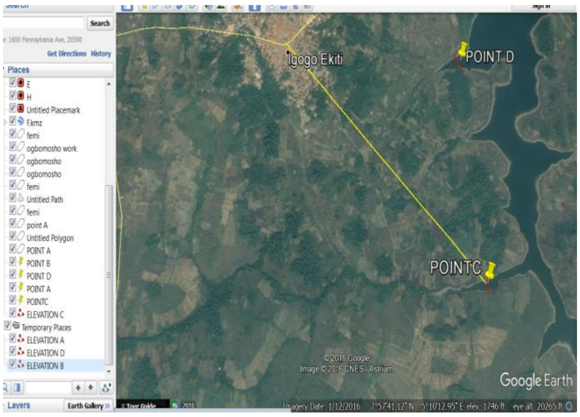

Fig 2 Showing the Distance Measurement of Location C From the Target

Table 1

Location	The distance of each location from the targeted supply(km)
A	6.11
B	5.30
C	4.14
D	2.76

2) *Measuring the Accessibility of Each Locations*

The accessibility to each site was evaluated through a recconaissance observation from the imagery. The distance of each location to the major road were measured and the presence of trees and thick vegetations that might cause the need for constructing a temporal route to the site for smooth transportation of material and labour were also checked for from the satelite imagery in order to rate the site as shown in Fig 3 for location A the same was repeated for others with the results shown in Table II

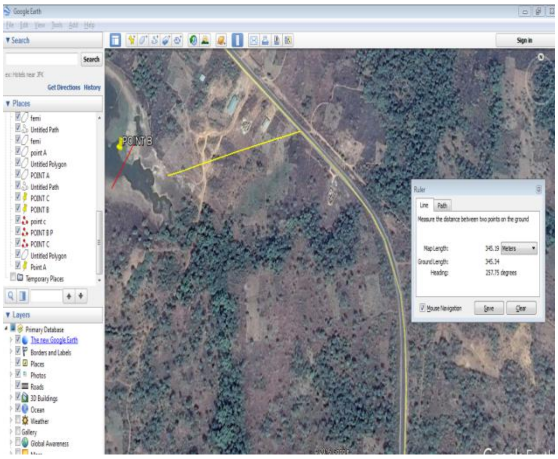

Fig 3 Measuring The Accessibility Of Location B

TABLE II

Locations	**Accessibility of each Location**		
	Accessibility	**Distance(m)**	**Vegetation**
A	Accessible	113	Not thick
B	accessible	345	Not thick
C	Inaccessible	700	Thick
D	Inaccessible	501	Thick

3) *Measuring the Geotechnical Condition (G.C.) of Each Locations*

The soil/geotechnical properties of each of the alternatives were determined through the use of ArcGIS and Remote sensor as shown in Fig 3 The purpose of which is to know the nature of the top soil and the subsoil of each of the alternatives and know the most suitable soil for the foundations of the dam walls and other sub structures for the water treatment. These properties of soil at various depths were determined and the characteristics of each soil present in each of the alternative location are shown in Table III and Table IV for location A and D the same was repeated for other locations

I. The soil classification was calibrated using the Nigeria soil classification system
II. The point locations were superimposed on the soil data
III. Values of soil properties were extracted onto the point features

The soil found common to the proposed area are the **Ferric lixisols** with a sub classification of **Dystric leptosols.** These are soils with subsurface accumulation of low activity clays and high base saturation over hard rock or in unconsolidated very gravelly material. This are found to be the same for all the alternative locations, with slight variation in the material components that make up the soil.

TABLE III

G.C.	**Geotechnical properties of location A**	
	Top Soil	Sub Soil
Texture	Sandy loam	Sandy loam
Soil phase	Inundic	Inundic
%Sand	57.1	46.9
% Clay	24.8	37.3
% Silt	18.1	15.6
Bulk density(kg/m^3	1.2	1.1
Amount of gypsum	0.1	0.5
Amount of Nitrogen	0.29	0.1
Erodibility	0.14-0.23	0.14-0.23
Soil pH	6.3	6.9

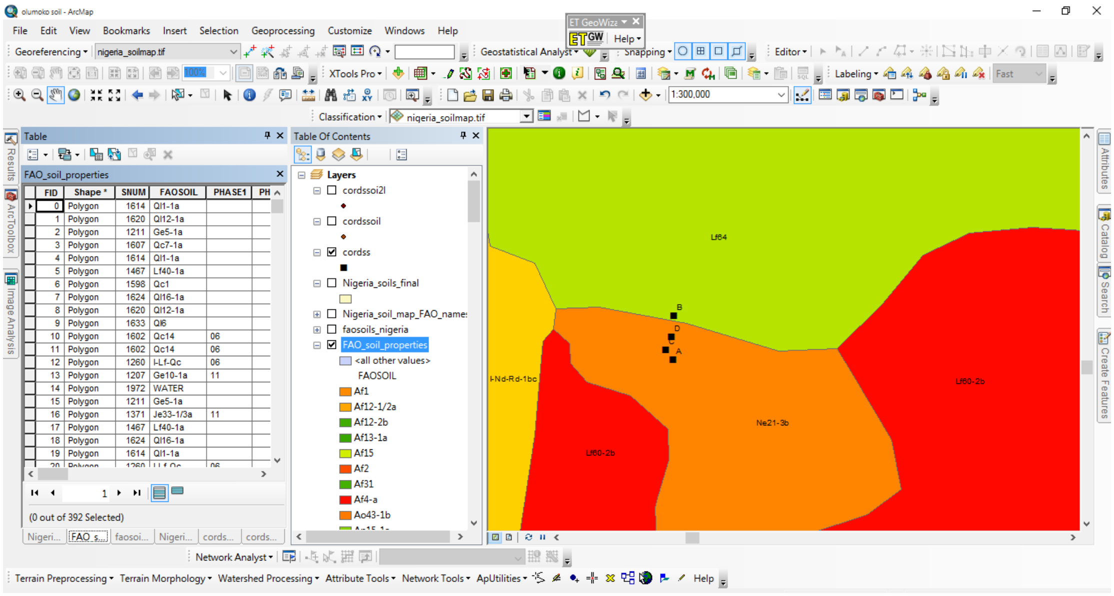

Fig 3 The Geotechnical Condition of Each Location from Arcgis and Remote Sensing

D. Determining the Surface and the Under Water Topography of Each Location

The bathymetric map of each of the alternatives i.e. the underwater topography and underwater profile of each of the alternatives were obtained using a combination of ArcGIS and remote sensing tools. The underwater topography shown in Fig 4 was first obtained using the remote sensing and analyzed on the ArcGIS to provide the digitized imagery and then the underwater profile of each of the alternatives were obtained as shown in Fig 5 for location A hereafter the surrounding average elevation of each of the locations where other sub structures were to be constructed were also measured as shown in Fig 6 and compared against the elevation of the targeted location to know if the water are going to be transported uphill or downhill with help of the topographic imagery of each of the locations. The elevation of location B is shown in Fig 6

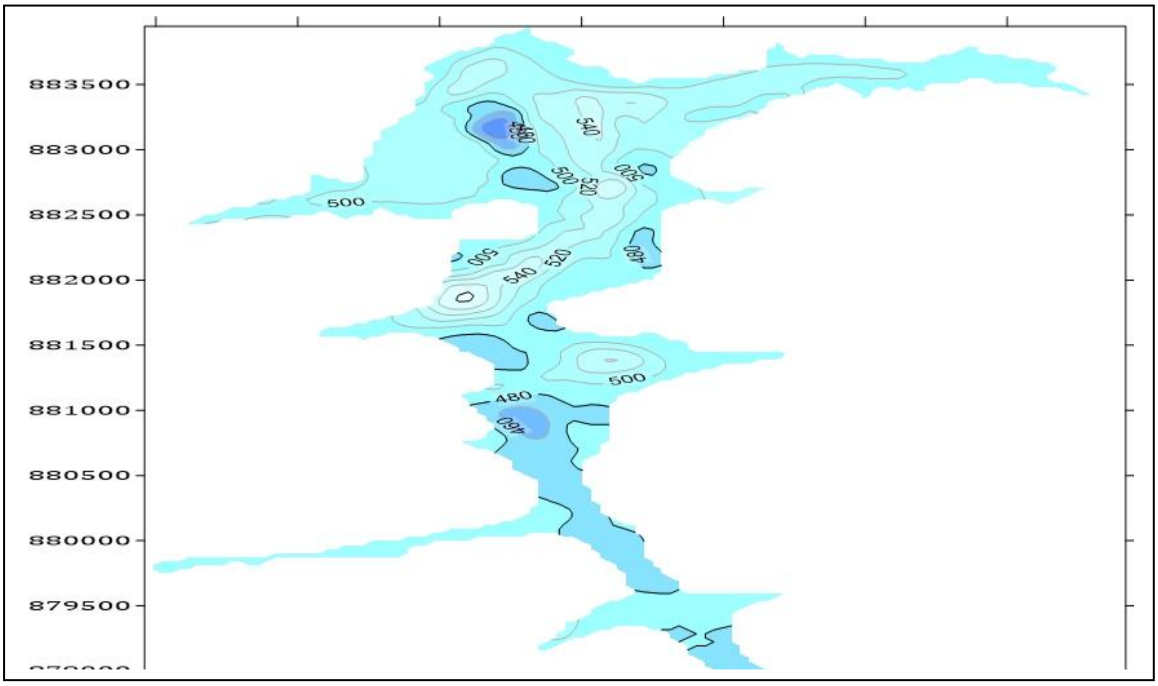

Fig 4 Digitized Underwater Topography of the IYE River

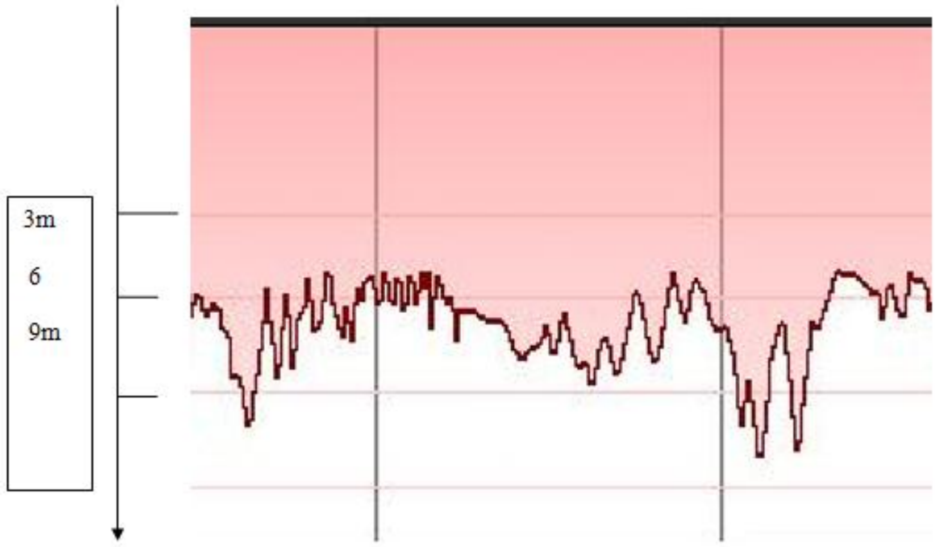

Figure 3.5 the underwater profile of Location A

Fig 5 under water profile of location A

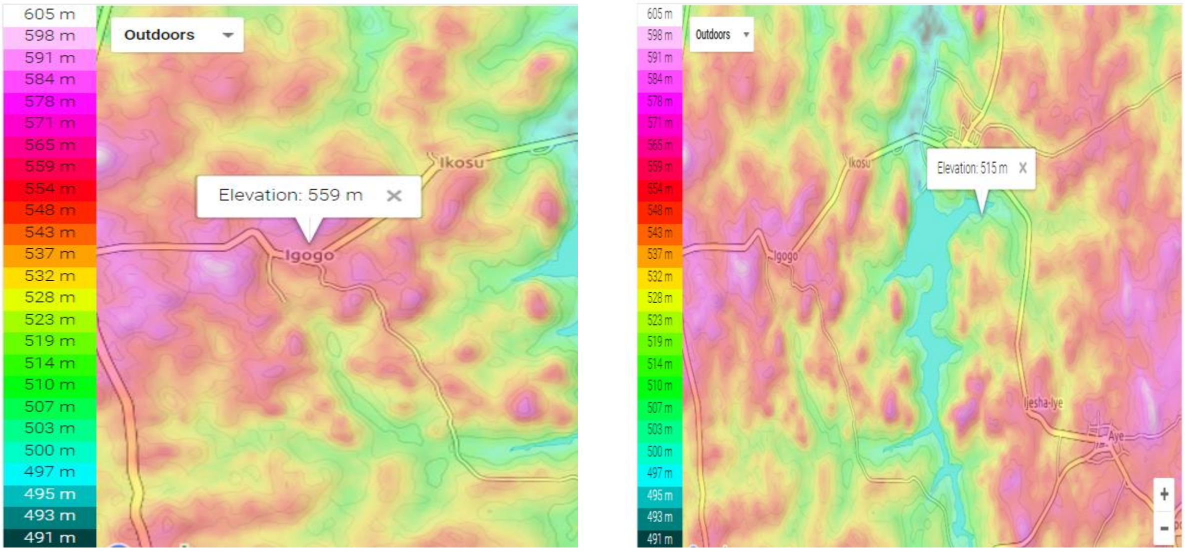

Fig 6 The elevation of location B against the elevation of the target location

The same was repeated for the other locations and the results shown in Table V. This provides an insight whether the water is to be transported uphill or downhill. Thereafter the surface profile of each locations were obtained

1) Measuring The Surface Profile Of Each Location

The surface profiles of each of the alternatives were obtained using a combination of ZONUM tools software and Google earth. The coordinates were first obtained from the Google earth and then the coordinates obtained were exported to the ZONUM TOOLS software. From where the exact satellite imagery of each of the alternatives were seen. Elevations of 3000 points were selected across the river path of each of the locations (from where the dam walls are to begin and end) for accuracy. The elevation coordinates were automatically generated by the ZONUM tools. The result extracted and the surface profile from the side cliffs down to the surface water level and back to the cliff were plotted on the excel graph to provide a clear modified surface profile of each locations

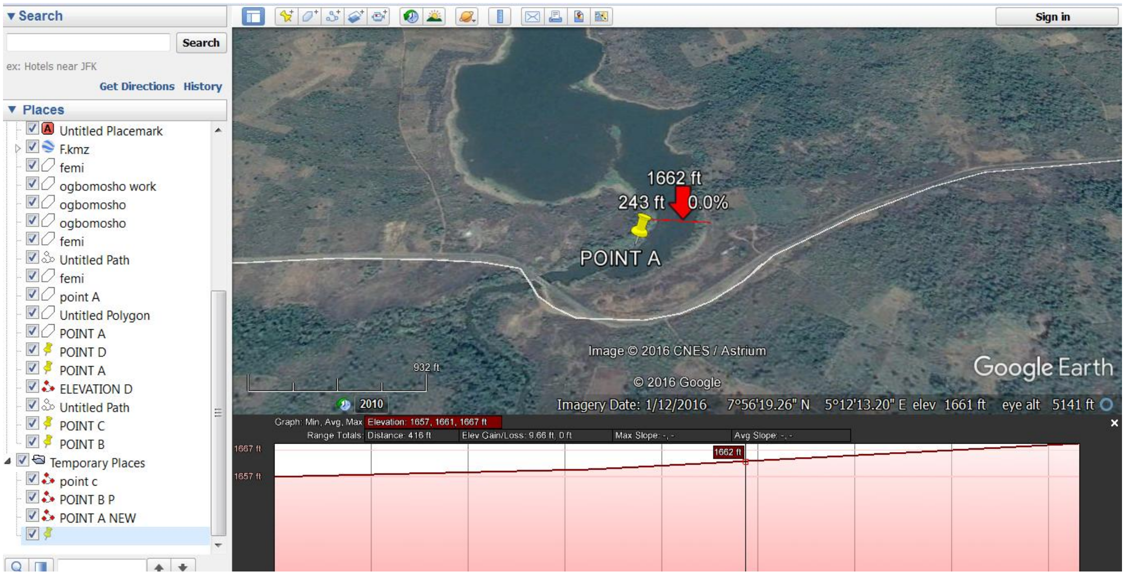

Fig 7 generating the surface profile of location A

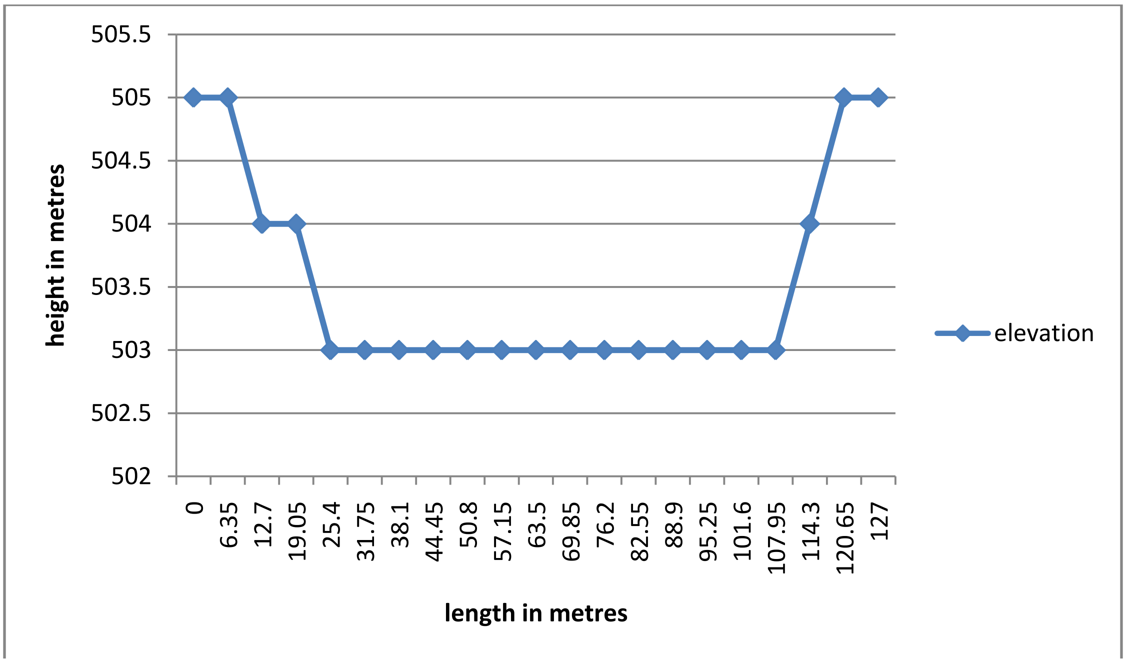

Fig 8 modified Surface Profile of Location A

The purpose of this is to provide a clear profile of each of the locations to be able to calculate the dam sections and estimate the volume of concrete needed for the dam construction work. These are shown in Fig 7 and Fig 8 The same was repeated for the other locations

E Estimating the Concrete Volume For Each Location to Obtain a Cost Estimate

Here the detailed concrete volume analysis was done alone for the dam section for all the 4 locations others such as estimation of earthworks to be excavated were not included. The expected dam capacity was obtained first by getting the population of the community using the 1991 and 2006 census and then using that to obtain the growth rate, from where the population was used to calculate the expected dam capacity using the World Health Organization Standard to obtain the yearly water consumption, From where the dam sections for each location were calculated to obtain the volume of concrete required.

The population of the area was used in obtaining the dam capacity from the national census as at 1991 the population of the area was about 45,210 as at 2006 the population was 122504. The growth rate is calculated from the difference in population/year interval from where the expected population in 2027 is calculated. The dam is expected to serve the community for 10 years

$$\frac{difference\ \ in\ population}{interval}$$

$$\frac{122504 - 45210}{15} = 5152.9$$

$$5152.9 \times 30 = 154587$$

This is added to the current population 154587+122504 = 277091

According to World Health Standard 150 litres of water is expected to be used per person for domestic purposes multiplying this by the population

277091 x 150 x 365= 1.52×10^{10} litres converting to m^3

$$\frac{1.52 \times 10^{10}}{1000} = 15200000m^3$$

Hence $152000000m^3$ is the expected dam capacity. The area of the location was obtained using digital means as shown in Figure A2 as $3657545m^2$ from where the height of the dam (H) was obtained.

$$H = \frac{volume}{area} = \frac{15200000}{3657545} = 4.15m$$

The total height of the dam (H_T) = Obtained Height + Height of Free board

The standard height for free board = 3m

H_T = 7.15m= 7m

The assumed width of the dam crest is 0.5m hence the base of the dam can be calculated. The Upside and Down side slope (U/S and D/S) are taken as 1:2

From here the upside and down slide slope the length of the base can be obtained by multiplying the slope with the height and adding the width of the crest.

14 + 0.5 + 14 = 28.5m

The volume of concrete required for each location can be obtained by multiplying the area with the length across the river.

Area of trapezium = 0.5(a + b)h = 0.5(0.5+28.5)7=$101.5m^2$ hence the same section was used for all with the difference coming from the length of each section across the river.

Location A =82m , Location B = 72m, Location C = 62m, Location D = 55m

Volume of concrete for A = Area x Length = 82 X 101.5 = $8323m^3$

B = 72 X 101.5 = $7308m^3$

C = 62 X 101.5 = $6293m^3$

D = 55 X 101.5 = $5582.5m^3$

TABLE V

locations	**Measuring the elevation of each location against the target elevation**	
	Elevation(m)	Elevation of target
A	510	559
B	515	559
C	512	559
D	511	559

F ADMINISTERING QUESTIONNAIRES

Here, based on the results obtained from the performance of each of the potential locations chosen with respect to the criteria under considerations questionnaires were served in order to attach fuzzy values to each of the locations for the ranking process. The following steps were followed.

1) ***Selection Of Team Of Decision Makers***

Here 4 teams of decision makers who are experts in dam construction works were selected.

1) Obtaining Decision makers opinion

17 decision makers responded from 3 companies and 1 Federal agency (Lower Niger River Basin) out of the questionnaires giving out they include

i. Stable Engineering Consultant
ii. Echo And Iga Engineering Company
iii. The Niger River Basin Authority
iv. Cewat Consulting Firm

These formed the decision team. Hence the 17 respondents were grouped into 4 teams. This is shown in Table VI

TABLE VI

Measuring the elevation of each location against the target elevation	
Decision Team	Total number of respondents
Stable Engineering Consultant	6
Echo And Iga engineering Company	6
Niger River Basin Authority	3
Cewat Consultants	2
Total	17

3) ***Attaching The Fuzzy Values To The Criteria And Alternatives:***

The concept of the fuzzy scale which was used to eliminate the vagueness that will definitely arise has a result of several decision makers involved were applied based on the results from the experts opinion using the Saaty's Fundamental Scale of Absolute Number. The fuzzy TOPSIS approach was used in order to allow for the vagueness that may occur in the cause of the experts' judgment. In the case of Saaty Fundamental Scale the scores are ranged from 1-9 and a linguistic variables are attached to each of the scores. These are shown in Table VII and Table VIII

TABLE VII

Linguistic variable for the evaluation of the criteria (kilic, 2012)	
Linguistic Variable	**Fuzzy Number**
Very Low (VL)	(0, 0, 0.1)
Low (L)	(0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1)
Very High (VH)	(0.9, 1, 1)

TABLE VIII

Linguistic variable for the evaluation of the alternatives (kilic, 2012)	
Linguistic Variable	**Fuzzy Number**
Very Poor(VP)	(0,0,1)
Poor(P)	(0,1,3)
Medium Poor(MP)	(1,3,5)
Fair(F)	(3,5,7)
Medium Good(MG)	(5,7,9)
Good(G)	(7,9,10)
Very Good(VG)	(9,10,10)

F Obtaining the decision makers response

The response from the decision makers grouped into 4 teams were obtained from the questionnaire. The average results coming from each respondent were obtained first. Hence the results coming from each team is the average of all the respondents in that team. The opinion of the decision makers on each criterion with respect to the goal and the locations with respect to each criterion were pooled through the questionnaire. The decision makers agreed in their choice of rating the criteria in relative to the goal this is shown in Table VIII but with variation arising in their choices of each locations with respect to each criterion. Table IX shows that of Criteria 1 and the performances of each location with respect that criterion according to the decision makers preference the fuzzy values are shown in Table X this was repeated for all the remaining criteria

IV RESULTS

TABLE IX

Showing the relative importance of the criteria to the goal	
Criteria	Decision Makers Opinion
Criteria	Decision Makers Opinion
C1	Medium
C2	Medium High
C3	Very High
C4	Medium

C5	High
C6	Medium

TABLE X

The opinion of the decision makers on the alternatives based on Criteria1

Location	DM1	DM2	DM3	DM4
A	VG	G	G	G
B	G	VG	G	G
C	MG	G	G	G
D	F	F	VG	VG

TABLE XI

Fuzzy representation of decision makers' opinion on the alternatives based on Criteria1

Location	DM1	DM2	DM3	DM4
A	9,10,10	7,9,10	7,9,10	7,9,10
B	7,9,10	9,10,10	7,9,10	7,9,10
C	5,7,9	7,9,10	7,9,10	7,9,10
D	3,5,7	3,5,7	9,10,10	9,10,10

The fuzzy values based on the performance of all the locations with respect to all the criteria are shown in Table XII from where the analysis by TOPSIS was used to select the best location as explained below. These fuzzy values for each of the locations based on the opinion of the Decision makers (DM) had been averaged for each row and the results for all the criteria are shown in Table XII the weights were obtained from the fuzzy scale in Table VIII

The Table XIII was normalized by dividing all the numbers in each row by the highest number in each row. For row 1 the highest number is 10 hence all the numbers in that row were divided by 10

The normalized fuzzy weight (NFW) of each alternative location was calculated using equation 1 multiplied by the fuzzy weights of each of the criterion

$$NFW = W \times I \quad (1)$$

Where

W is the weight of each criterion

I is the fuzzy value of each locations under each criterion

This result is Presented in Table XIV

The next thing was to identify the fuzzy positive ideal alternatives and the fuzzy negative ideal alternatives and the distance of each of the alternative from the fuzzy ideal conditions are identified.

The fuzzy positive ideal condition is the one with the highest fuzzy number for each of the criteria while the fuzzy negative ideal condition is the one with the lowest fuzzy number for each of the criteria. A set of the Fuzzy positive ideal number and the fuzzy negative ideal number are determined.

TABLE XII

The averaged fuzzy representation of decision makers opinion on the alternatives						
location	C1	C2	C3	C4	C5	C6
A	7.5,9.2,10	7,9,10	7,9,10	7,9,10	3,5,7	9,10,10
B	7.5,9.2,10	8.5,9.8,10	7,9,10	0,1,3	5,7,9	7,5,10
C	6.5,8.5,9.8	0,1,3	7,9,10	9,10,10	8.5,9.8,10	1,3,5
D	6,7.5,8.5	3,5,7	5,7,9	9,10,10	7.5,9.3,10	7,9,10
Weights	0.3,0.5, 0.7	0.5,0.7,0.9	0.9,1,1	0.3,0.5,0.7	0.7, 0.9,1	0.3,0.5,0.7

Take the fuzzy positive ideal solution to be P= (V_1*,V_2*,V_3*……V_i^*) and the fuzzy negative ideal solution to be N= (V_1^-,V_2^-…….V_i^-) respectively such that
V_i^*= (1,1,1) and V_i^- =(0,0,0) now the distance of each alternative from the positive ideal solutions based on each of the criteria is evaluated using the formula

$$d_i^+ = \sum_{i=1}^{n} d\left(v_{ij}, v_i^*\right) \qquad (2)$$

$d_i^+ =$ distance from the positive ideal solution
$d\left(v_{ij}, v_i^*\right)$ = fuzzy value for each criterion
The distance of the first alternative from (1,1,1) based on the formula above is shown below as obtained from Table XIV
$d_1^+ =$ d[(0.23,0.46,0.7),(1,1,1)]+ d[(0.35,0.63,0.9),(1,1,1)] + d[(0.63,0.9,1),(1,1,1)] + d[(0.21,0.45,0.7),(1,1,1)]+ d[(0.21,0.45,0.7),(1,1,1)]+ d[(0.27,0.5,0.7),(1,1,1)]
This is solved using the formula in equation (2)

$$\frac{1}{2}\{(max|m_l - 1|, |m_u - 1| + |m_m - 1|)\}$$

Where $m_l = lower\ fuzzy\ number$
$m_u = upper\ fuzzy\ number$
$m_m = middle\ fuzzy\ number$

TABLE XIII

The normalized fuzzy representation of decision makers opinion on the alternatives						
Location(i)	C1	C2	C3	C4	C5	C6
A	0.75,0.92,1	0.7,0.9,1	0.7,0.9,1	0.7,0.9,1	0.3,0.5,0.7	0.9,1,1
B	0.75,0.92,1	0.85,0.98,1	0.7,0.9,1	0,0.1,0.3	0.5,0.7,0.9	0.7,0.5,1
C	0.65,0.85,0. 98	0,0.1,0.3	0.7,0.9,1	0.9,1,1	0.85,0.98,1	0.1,0.3,0. 5
D	0.6,0.75,0.8	0.3,0.5,0.7	0.5,0.7,0.9	0.9,1,1	0.75,0.93,1	0.7,0.9,1

TABLE XIV

	C1	C2	C3	C4	C5	C6
A	0.23,0.46, 0.7	0.35,0.63, 0.9	0.63,0.9,1	0.21,0.45,0. 7	0.21,0.45, 0.7	0.27,0.5,0. 7
B	0.23,0.46, 1	0.43,0.69, 0.9	0.63,0.9,1	0,0.05,0.21	0.35,0.63, 0.9	0.21,0.25, 0.7
C	0.19,0.43, 0.69	0,0.07,0.2 7	0.63,0.9,1	0.27,0.5,0.7	0.59,0.88, 1	0.03,0.15, 0.35
D	0.18,0.38, 0.85	0.15,0.35, 0.63	0.45,0.7,0.9	0.27,0.5,0.7	0.53,0.84, 1	0.21,0.45, 0.7

The calculations for the fuzzy positive ideal solution for the first location is shown below using equation 2 and the results in Table XIV

$$= \frac{1}{2}\{(max|0.23-1|,|0.70-1|+|0.46-1|)\}+\frac{1}{2}\{(max|0.35-1|,|0.90-1|+|0.63-1|)\}+\frac{1}{2}\{(max|0.63-1|,|1-1|+|0.9-1|)\}+\frac{1}{2}\{(max|0.21-1|,|0.70-1|+|0.45-1|)\}+\frac{1}{2}\{(max|0.21-1|,|0.70-1|+|0.45-1|)\}+\frac{1}{2}\{(max|0.27-1|,|0.70-1|+|0.5-1|)\}$$

$$d_1^+ = 0.655+0.51+0.235+0.67+0.67+0.615$$

$$\mathbf{d_1^+ = 3.355}$$

$$d_1^- = \frac{1}{2}\{(max|0.23-0|,|0.70-0|+|0.46-0|)\}+\frac{1}{2}\{(max|0.35-0|,|0.90-0|+|0.63-0|)\}+\frac{1}{2}\{(max|0.63-0|,|1-0|+|0.9-0|)\}+\frac{1}{2}\{(max|0.21-0|,|0.70-0|+|0.45-0|)\}+\frac{1}{2}\{(max|0.21-0|,|0.70-0|+|0.45-0|)\}+\frac{1}{2}\{(max|0.27-0|,|0.70-0|+|0.5-0|)\}$$

$$d_1^- = 0.58+0.765+0.95+0.575+0.575+0.6$$

$$\mathbf{d_1^- = 4.045}$$

TABLE XV

The separation measures of each of the Locations		
LOCATIONS	Positive Solution d_i^+	Negative Solution d_i^-
A	3.355	4.045
B	3.585	4.07
C	3.925	3.47
D	3.495	4.00

The next thing is to calculate the closeness coefficient which is a representation of how each alternative is close to the ideal solution.

The closeness coefficient CC_I is calculated using the formula

$$CC_i \quad \frac{d_i^-}{d_i^- + d_i^+}$$

$$CC_1 = \frac{4.045}{3.355+4.045} = 0.547$$

$$CC_2 = \frac{4.07}{3.585+4.07} = 0.532$$

$$CC_3 = \frac{3.47}{3.925+3.47} = 0.469$$

$$CC_2 = \frac{4.00}{3.495+4.00} = 0.534$$

TABLE XVI

The separation measures of each of the alternatives and the closeness coefficient

LOCATION	Positive Solution d_i^+	Negative Solution d_i^-	Closeness coefficient CC_i
A	3.355	4.045	0.547
B	3.585	4.07	0.532
C	3.925	3.47	0.469
D	3.495	4.00	0.534

According to the ranking based on TOPSIS, Location A with closest to the Positive ideal Solution (PFS) and Farthest from the Negative ideal Solution (NFS) is the best alternative for the location of the Dam site as shown in Table XVI. the closeness to the ideal solution is shown in Fig 9 where the upper limit of 1 represent the Positive ideal solution(PIS) and the lower limits of 0 represents the negative ideal solution (NIS) the closer a location is to PIS the more suitable it is for the dam construction The final ranking are shown in Fig 10

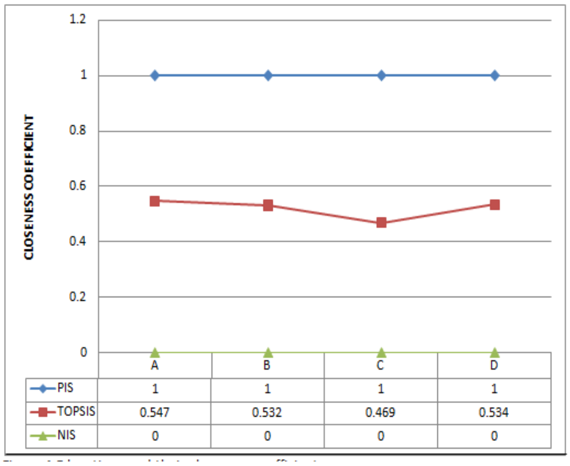

Fig 9 the locations with their closeness coefficient

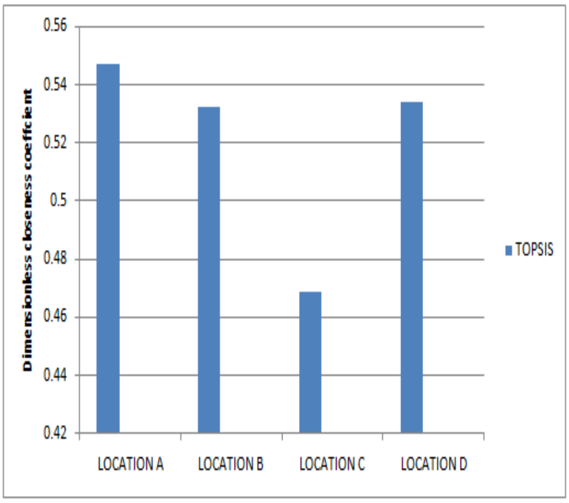

Fig 10 the locations with their ranking by TOPSIS

The closeness of each of the locations to the positive ideal location i.e. that location that will satisfy all the criteria perfectly was used in selecting the best dam site. The closer a location is to the ideal solution the better is that particular location for the dam construction. TOPSIS also provided additional information. From here we could see very clearly that even the best alternative is just a little above the average (0.547). In a situation whereby all the alternatives fall below the average even though we will still have a preferred option yet the properties of that preferred option needs to be worked on for better performance during service.

V. CONCLUSION

3 out of the 4 locations selected for the dam construction have their closeness to the ideal solution above the average.
Lower value than 0.5 means the dam location selected isn't suitable for the dam construction work according to TOPSIS

Criteria 3 which is the geotechnical condition of the locations was rated as the most important criteria to be considered during dam site selection by the experts.

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REFERENCES

[1] Allesio, I., Philippe N. Multi-Criteria decision analysis: Methods and Software. John Wiley and sons publishers, West Sussex, United Kingdom. 2013
[2] Aruldoss M ; Lakshmi T.M. ; Venkatesan V.P. A survey on Multi criteria Decision Making Methods and its application. American Journal of Mechanical Engineering 2013
[3] Ayan M.B. A fuzzy AHP Approach for Supplier selection Problem. A journal of management science and supplier chain pp 16-18 2013
[4] Beck, J.; Chan, E.; Irfanoglu, A. ; Papadimitriou, C.Multi-criteria optimal structural design under uncertainty, Earthquake Engineering and Structural Dynamics, pp, 741–61. 1999
[5] Belton V, Steward T. Multiple criteria decision analysis: An integrated approach. Boston (MA), USA. pp 1-14, 2002
[6] Gregory A.K., Todd S.B., Arun V., Thomas P.S., Linkov I., Application of Multi Criteria decision analysis in Environmental decision making. A Journal of integrated environmental assessment and management. Vol 1, No 2. pp 98-108. 2005
[7] Kilic, H.S., "An integrated approach for supplier selection in multi item/multi supplier environment", Applied Mathematical Modelling, Vol. 37 pp 14-15. 2013
[8] Khoshnoudian F., Tabrizi A.M. Responses of Isolated Building with MR Dampers and Fuzzy Logic. International Journal of Civil Engineering. Vol 10 pp 224. 2012
[9] Linkov, I.; Sahay, S.; Kicker, G.; Bridges T.; Seager T.P. Multi-Criteria decision analysis: A framework for managing contaminated sediments. Proceeding of Strategic management of Marine Ecosystem. Kluwer, Amsterdam. 2004
[10] McCartney, M. P.; Sullivan, C.; Acreman, M. C. Ecosystem impacts of large dams. Report to IUCN, UNEP and WCD. Centre for Ecology and Hydrology, Wallingford, UK. pp 81 2007
[11] Minatour Y; Khazaie J; Ataei M; Javadi A An integrated support decision system for dam site selection. A journal of the university of sheriff. pp 319-330. 2014