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A Preference Ranking of possible locations for the construction of Hydroelectric Power Plants in India

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Abstract: Construction of Hydroelectric power plants comprise challenging applications of modern time series forecasting and are essential to the success of many businesses. In this paper, preference ranking is based on PROMOTHEE method. Firstly the dataset that extract linear characteristics of hydroelectric power plants are identified. Secondly, the PROMOTHEE method is used for the nonlinear combination ranking model of different power plants. Empirical results obtained reveal that the ranking by using the nonlinear combination model is generally better than those obtained using other models presented in this study in terms of the same evaluation measurements. Those results show that that the proposed nonlinear modeling technique is a very promising approach to real time series ranking.

Keywords: PROMOTHEE, hydroelectric, nonlinear, ranking, accuracy

INTRODUCTION

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010, and is expected to increase about 3.1% each year for the next 25 years.

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The force of the water being released from the reservoir through the dam spins the blades of a giant turbine. The turbine is connected to the generator that makes electricity as it spins. After passing through the turbine, the water flows back into the river on the other side of the dam.

In the recent years demand of electricity is increasing and the safe, renewable and eco friendly way to quench the thirst for electricity is hydro electricity. Thus a huge demand for hydro electric power plants.

II VARIOUS FACTORS CONSIDERED BEFORE CONSTRUCTION

A. Availability of raw materials and machinery: The materials used in the construction of dams determine whether it will last for long or effectively serve its purpose. The materials that are used to make the walls of the dam should be able to hold the force of the water. This means that the site for the dam should be at a place where these materials, such as cement and ballast, can be easily found. It is crucial to use high-quality materials to prevent disasters, such as water flooding in areas near the dam.

B. Availability of Labour: Construction of dams require a large amount of labour and work force.

C. Variety and Availability of Flora: The variety and availability of flora affects the decision of choosing a location for the construction, both the factors have an inverse relation i.e., if the location has a high variety and availability of flora then the construction of a dam is unfavourable.

D. Variety and Availability of Fauna: The variety and availability of fauna affects the decision of choosing a location for the construction, both the factors have an inverse relation i.e., if the location has a high variety and availability of fauna then the construction of a dam is unfavorable.

E. Human Population: Usually when large scale construction projects such as hydro electric power plants are considered the human population plays a deciding role as it involves rehabilitation of large masses of people. The contribution of this parameter is inversely proportional to the favourability of the construction.

F. Geological Structure: The station should be located in a place where the land or the rock structure on which the dam will be built on is strong enough to hold the weight and the force of the water in the dam. The walls should have a capability of holding and sustaining both visible and invisible forces, whether man-made or natural. The rock structure should have the capability of withstanding an earthquake and it should not allow seepage of water, since this weakens the dam. The walls should be waterproof to avoid being weakened by water.

G. Climate of The Location: Climate change is projected to decrease water availability, change peak flow periods, increase extreme weather events, alter precipitation patterns, and increase temperature. Lower stream flow will impact the productivity of hydropower dams in the Rio Grande basin. Overall, lower stream flows will lead to lower reservoir levels

(Llewellyn & Vaddey 2013), resulting in decreased in hydropower generation.

H. Earthquake Zone of the Location: If dam is situated in an earthquake zone, its design must include earthquake forces. The type of structure best suited to resist earthquake shocks without danger are earthen dams and concrete gravity dams. We are assuming that if a location lies in an earthquake prone zone then the construction is unfavourable.

I. Spillway Size and Location: Spillway disposes the surplus river discharge. The capacity of the spillway will depend on the magnitude of the floods to be by-passed. The spillway is therefore much more important on rivers and streams with large flood potential.

J. Height of the Dam: Earthen dams are usually not provided for heights more than 30 m or so. For greater heights, gravity dams are generally preferred.

III. LITERATURE REVIEW

The concept of decision making has become quite common in our everyday life. We are required to make decisions at every step There are many definitions of decision-making process: according to H. Koontz and H. Weihrich [3] the decision is defined as choice of the most suitable alternative with respect to the predefined criteria, while T. Hunjak [4] defines it as collection of activities from the problem definition to the alternative selection. PROMETHEE I and PROMETHEE II methods are developed by J. P. Brans and presented for the first time in 1982 at the conference "L'ingénièrie de la decision" organized at the University of Laval in Canada [6]. In the same year, several practical examples of application of the methods were presented by G. Davignon [7], and several years later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV methods [8,9]. The same authors also suggested visual, interactive modulation GAIA, which represents a graphic interpretation of the PROMETHEE method, and in 1992 and 1995, they suggested two more modifications – PROMETHEE V and PROMETHEE VI [10, 11]. Many successful implementations of the PROMETHEE method to various fields are evident, and as such, these methods have found their place in banking, investments, medicine, chemistry, tourism, etc

[12]. Opricovic and Tzeng (2007) proposed PROMETHEE as a tool, in comparison with three MCDA methods, to rank six alternative hydropower systems on the Driana River based on eight criteria [1, 2]., Morais and de Almeida (2006) employed a group decision-making on PROMETHEE [1,5]. Raju and Pillai (1999a) proposed an extension of PROMETHEE in a distance-based environment to select the best reservoir configuration for river basins [1,13]. Furthermore, in order to select the best alternative in irrigation development strategies, Raju and Pillai (1999b) applied PROMETHEE with the Taguchi experimental method and stochastic extension of PROMETHEE [1,14]. Morais and De Almeida (2007) proposed a group decision-making model based on PROMETHEE GDSS procedure, which took into account the points of view of four stakeholders, and PROMETHEE V method, which selected feasible options under available budget constraints, to develop a leakage management strategy [1]. In the field of water management strategies assessment, Simon et al. (2004, 2005, 2006) employed PROMETHEE I and II to evaluate water management strategies [1,12].In order to take into account the equity issues in the greenhouse gases emission rights allocation process, Vaillancourt and Waaub (2004) used PROMETHEE II to rank regions or countries, by considering their own characteristics, their perceptions of equity and the different economic, social, and environmental stakes countries [1,11].

IV. INTUITION METHOD

The conversion of a crisp data set into a fuzzy data set is done using Intuition Method. The data for the various factors mentioned above is gathered according to specific potential locations and using the method of intuition is converted into a fuzzy data set having values between [0,1]. This fuzzy data set is then subjected to the following optimization algorithm.

V. PROMETHEE METHOD

PROMETHEE I and PROMETHEE II methods are developed by J. P. Brans and presented for the first time in 1982 at the conference "L'ingénièrie de la decision" organized at the University of Laval in Canada. In the same year, several practical examples of application of the methods were presented by G. Davignon, and several years later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV methods. The same authors also suggested visual, interactive modulation GAIA, which represents a graphic interpretation of the PROMETHEE method, and in 1992 and 1995, they suggested two more modifications – PROMETHEE V and PROMETHEE VI. Many successful implementations of the PROMETHEE method to various fields are evident, and as such, these methods have found their place in banking, investments, medicine, chemistry, tourism, etc.

Algorithm

Applying PROMETHEE II evaluation method. A is a set of alternatives and C is the set of criteria.

Steps:

1) We use two preference functions in our calculations. In order to facilitate the selection of specific preference function, six basic types of this preference function are proposed to decision maker by Brans and Vincke (1985) . (In our calculations, we are using Type V: Linear Criterion)

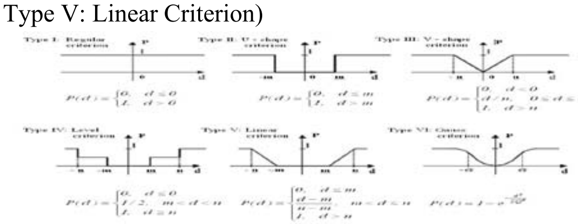

Fig. 2 Types of preference functions $P(d)$ with parameters that illustrate them

2) We use the preference functions (f & g) to calculate the preference degree (P). The value of preference degree varies between 0 and 1.

$$P_{j\,(a,b)} = G_j\left[f_j(a) - f_j(b)\right],$$

$$0 \leq P_{j\,(a,b)} \leq 1,$$

3) e assign a weight age to all the criteria after discussing about the importance of each criterion with the experts. The summation of all the weights assigned should be equal to 1.
(In our calculations C1 and C2 have been assigned 0.25, C3 and C4 have been assigned 0.2 and 0.1 has been assigned to C5.

4)

$$\pi(a,b) = \frac{\sum_{j=1}^{n} \omega_j P_j(a,b)}{\sum_{j=1}^{n} \omega_j},$$

The value of overall preference index (π) is calculated for each alternative a (a, b ε A) which is calculated by multiplying weight with the corresponding preference degree and then summation of the product for all criteria.

5)

$$\Phi^{+}(a) = \sum_{x \in A} \pi(x,a),$$

$$\Phi^{-}(a) = \sum_{x \in A} \pi(a,x),$$

Φ+ is defined as the outranking character of a which defines how much a dominates all the other alternatives in A. φ- is defined as the entering flow for a which determines how much a is dominated by all the other alternatives in A.

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a),$$

6) Φ is defined as net flow which determines the ranking of the alternatives using PROMETHEE II Evaluation method. The higher the value of Φ, the better the ranking will be.

VI. PROCEDURE & IMPLEMENTATION

Now we implement Promethee II method for the ranking procedure of hydroelectric power plants for various locations. The sample data used is input in the program developed using the above stated algorithm. Based on expert analysis we use intuition method to give the initial fuzzy values to each affecting factor/attribute. Promethee II algorithm implementation requests the number of factors to be considered for the ranking procedure. There can be a number of factors as mentioned above. The Promethee II method requires the weight values which are provided by the experts. The Preference Degree is calculated using the operations performed using the preference functions. The values of these preference functions are calculated using the Linear Criterion formula having values **m=0, n=6(for F) and m=-0.8, n=0.8(for G)**. The implemented code is executed on Java platform. This program when executed inputs the values of m & n which calculates the preference degree. The overall preference index (π) is calculated once the preference degree is obtained. After this the outranking character and entering flow is calculated. The code generates the ranks which are analysed on the basis of net flow(Φ).

Locations:

1. Deoli, Rajasthan
2. Mettur, Salen District, Tamil Nadu
3. Krishnarajasagara, across Kaveri River, Mysore
4. Narmada Nagar Valley, Mundi
5. Idukki, Kerala
6. Tehri, Uttrakhand
7. Bhakra Nagal, Himachal Pradesh
8. Jawahar Sagar, Rajasthan
9. Lakhwar, Uttrakhand
10. Bargi, Madhya Pradesh

Factors:

1. Availability of raw materials and machinery
2. Availability of Labour
3. Variety and Availability of Flora
4. Variety and Availability of Fauna
5. Human Population
6. Geological Structure
7. Climate of The Location
8. Earthquake Zone of the Location
9. Height of the Dam
10. Spillway Size and Location

Now formulation of a tabular representation is done with the columns as the various above mentioned factors/attributes and rows as all the above mentioned potential locations. For the sake of simplicity in the table we rename the columns alphabetically i.e., a, b, c, d...till 10th factor/attribute and the rows as 1, 2, 3, 4...till 10th location.

The sample data is then used to calculate the ranking of the locations on the basis of the diverse intuition value weights to given to them by expert analysis. The following screenshots are of the Promethee II implementation code running on the sample data.

x\y	a	b	c	d	e	f	g	h	i	j
Wts	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
1	4.3	3	1.2	2.5	0.9	2	1.2	1	3	1.2
2	2	2	0.9	3.1	1.6	3	3.3	4	1	2.7
3	2.5	5	0.2	2.2	3.7	1	1.5	1	1.2	4.2
4	3.1	1.4	2.6	4.0	4.0	4	4.1	2	3.5	2.9
5	4.9	1.8	3.1	0.7	3.2	2	2.2	3	1.8	3.9
6	4.7	4.3	4	4.9	4.1	4	4.5	4	4.4	4.7
7	3.9	2.5	3.7	1.2	2.8	1	2.1	2	1.2	1.1
8	4.1	4.6	3.8	0.7	3.5	3	0.4	3	3.7	2.0
9	1.5	1.6	4.0	2.3	2.1	1	3.5	1	1.4	1.8
10	2.5	1.8	1.2	1.2	1.9	2	1.9	1	2.9	3.3


```
Enter number of alternatives: 10
Enter number of criteria: 10


Enter the name of alternative 1: Deoli
Enter the name of alternative 2: Mettur
Enter the name of alternative 3: Krishna
Enter the name of alternative 4: Narmada
Enter the name of alternative 5: Idukki
Enter the name of alternative 6: Tehri
Enter the name of alternative 7: Bhakra
Enter the name of alternative 8: Jawahar
Enter the name of alternative 9: Lakhwar
Enter the name of alternative 10: Bargi

Enter the name of criterion 1: Raw Materials
Enter the name of criterion 2: Labour
Enter the name of criterion 3: Flora
Enter the name of criterion 4: Fauna
Enter the name of criterion 5: Human Population
Enter the name of criterion 6: Geological Structure
Enter the name of criterion 7: Climate
Enter the name of criterion 8: Earthquake Zone
Enter the name of criterion 9: Height
Enter the name of criterion 10: Spillway Size

For alternative 1: Deoli
Enter value for criterion 1: 4.3
Enter value for criterion 2: 3
Enter value for criterion 3: 1.2
Enter value for criterion 4: 2.5
Enter value for criterion 5: 0.9
Enter value for criterion 6: 2
Enter value for criterion 7: 1.2
Enter value for criterion 8: 1
Enter value for criterion 9: 3
Enter value for criterion 10: 1.2

For alternative 6: Tehri
Enter value for criterion 1: 4.7
Enter value for criterion 2: 4.3
Enter value for criterion 3: 4
Enter value for criterion 4: 4.9
Enter value for criterion 5: 4.1
Enter value for criterion 6: 4
Enter value for criterion 7: 4.5
Enter value for criterion 8: 4
Enter value for criterion 9: 4.4
Enter value for criterion 10: 4.7

Enter weight value for criterion 1: 0.1
Enter weight value for criterion 2: 0.1
Enter weight value for criterion 3: 0.1
Enter weight value for criterion 4: 0.1
Enter weight value for criterion 5: 0.1
Enter weight value for criterion 6: 0.1
Enter weight value for criterion 7: 0.1
Enter weight value for criterion 8: 0.1
Enter weight value for criterion 9: 0.1
Enter weight value for criterion 10: 0.1

Applying LINEAR CRITERION as Preference Function for both function f as well as function G
Enter value of m for function f: 0
Enter value of n for function f: 6

Enter value of m for function G: -0.8
Enter value of n for function G: 0.8
```

Value of function f

0.7167	0.5	0.2	0.4167	0.15	0.3333	0.2	0.1667	0.5	0.2
0.3333	0.3333	0.15	0.5167	0.2667	0.5	0.55	0.6667	0.1667	0.45
0.4167	0.8333	0.0333	0.3667	0.6167	0.1667	0.25	0.1667	0.2	0.7
0.5167	0.2333	0.4333	0.6667	0.6667	0.6667	0.6833	0.3333	0.5833	0.4833
0.8167	0.3	0.5167	0.1167	0.5333	0.3333	0.3667	0.5	0.3	0.65
0.7833	0.7167	0.6667	0.8167	0.6833	0.6667	0.75	0.6667	0.7333	0.7833
0.65	0.4167	0.6167	0.2	0.4667	0.1667	0.35	0.3333	0.2	0.1833
0.6833	0.7667	0.6333	0.1167	0.5833	0.5	0.0667	0.5	0.6167	0.3333
0.25	0.2667	0.6667	0.3833	0.35	0.1667	0.5833	0.1667	0.2333	0.3
0.4167	0.3	0.2	0.2	0.3167	0.3333	0.3167	0.1667	0.4833	0.55

Location	Ranking
Deoli	-1.1541375000000014
Mettur	-0.46663749999999915
Krishna	-0.6957625000000007
Narmada	1.1998625
Idukki	0.15836250000000085
Tehri	3.6999874999999998
Bhakra	-0.9041375
Jawahar	0.6166125000000005
Lakhwar	-1.1750125000000016
Bargi	-1.2791374999999992

After the completion of the method, as we can see Tehri has the maximum value among all the other alternatives/locations thus it is the best suited/favoured location and Bargi having the minimum rank is the worst alternative/location for the construction of a Hydroelectric power plant.

VII. CONCLUSION

As the world is struggling with energy crisis there is an urgent need to harness renewable energy. One of the major sources of renewable energy is a Hydroelectric power plant. Promethee II method is incorporated in the above ranking analysis method. The primary aim of this method is to facilitate the thorough analysis of the possibility of constructing a large scale hydroelectric power plant. This method distinguishes itself as an efficient, quick and effective one. The range and diversity of sample data used gives the exact indication of the accuracy this procedure embodies.

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