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SELECTION OF A SITE FOR INSTALLATION OF A WINDMILL USING MCDM

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Abstract – Multi criteria decision making is the most well-known branch of decision making, In this Paper a case study of Site Selection is taken for installation of windmill. Six Land Sites are selected for installation of windmill and the data has been collected in order for better understanding the best site. An analysis of six locations is analysed using PROMOTHEE.

Keywords- Promothee, Weight, Ranking, Normalized matrix, pairwise comparison, Beneficial, Non-beneficial

I. INTRODUCTION

Currently, ozone depletion, rising global average temperatures, natural change, various types of pollution, and reliance on oil-based commodities are some of the major concerns confronting humanity [1]. Consequently, the remaining reserves of coal, oil, and gas will run out in a short of time. As a result, one of the ways that many industrialised countries have used throughout the years have to deal with these challenges and to some extent is the broad deployment of massive and legitimate force sources [2]. Such imperativeness, particularly wind imperativeness, has become economically sensible and is well regarded by all authorities in regards to this issue as a result of the advancement of practicable force source development and its accompanying benefits, such as reduced pollution, wealth, and immutability [3]. Like other renewable energy sources, wind is abundant and diversified geologically, but it is also scattered, decentralised, and is erratic and variable nature [4]. The model weights, which will be utilised in the TOPSIS computation to rank the bicycles based on execution scores, are chosen using the Analytical Hierarchy Process (AHP) method [5]. The suggested approach for determining the best bicycle from 10 possibilities was developed using the MCDM strategy [6].

The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) method, which is based on AHP and utilized to select the ideal site location for wind energy projects, was described in this study [7]. This task is to determine the optimal location for a wind energy plant in India. The authors identified six wind energy criterion projects spread across India for their analysis [8]. The following seven factors were taken into consideration while determining the ideal location: wind power, hub height, distance, cost, CO2 emissions, and blade height. To achieve the study's goal, AHP is combined with PROMETHEE [9]. Then, using Analytical Hierarchy, determine the weights of each criterion. These weights will be used to choose the best project using the PROMETHEE II approach. A case study is done demonstrate how the methodologies were used to evaluate six different types of wind generation installation [11]. According to the AHP-PROMETHEE results, the horizontal wind power project is the best of the six projects.

II STRUCTURE OF DECISION PROBLEM

There are several sub-methods in PROMETHEE, which is a method comparable to ELECTRE, which has numerous iterations and is one of the top methods [14]. Today we must choose the finest wind power plant from a pool of six. Wind power, hub height, distance, cost, CO2, wind speed, and blade height are the criteria.

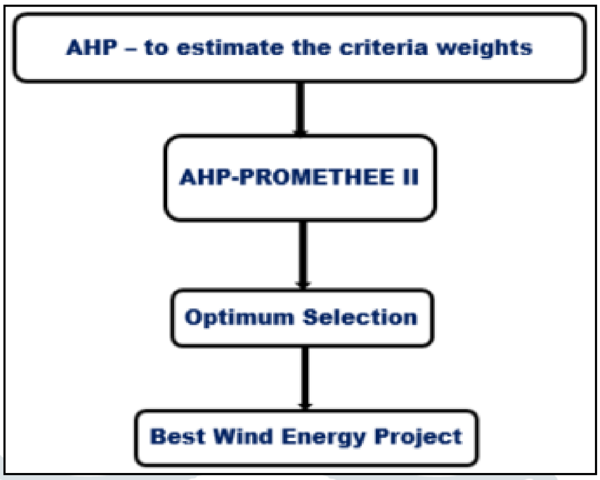

Figure 1: Process for choosing a windmill

The best windmill out of the six should next be identified by estimating the criteria weights using AHP. Using an MCDM approach such as PROMETHEE II and these criterion weights, determine the rankings for all projects. Sort the projects by net outflow or score to finish. Information on numerous wind energy projects in India may be found online.

Criteria Project	Wind power (MW)	Hub height (m)	Distance (m)	Cost (crores)	CO_2 (million tonnes reduced)	Wind speed (m/s)	Blade height (m)
Vertical	1064	120	1700	14500	0.21	15.3	70
Horizontal	1500	120	1900	10500	4.2	19	60
Lower land	650	120	2000	8000	1.75	5	80
Upper Land	150	120	1500	6000	1	2	50
Open Land	56.1	120	2500	4000	1.29	5	70
Agriculture land	6	78	2600	2000	0.9	11	30

Table 1: Windmill projects data

Criteria	Wind Energy Project
CR1 - Wind power (Mega Watts) CR2 - Hub height (meters) CR3 – Distance (meters) CR4 – Cost (crores) CR5 – CO_2 (million tonnes reduced) CR6 - Wind speed (meters/second) CR7 - Blade height (meters)	WEP1 – Vertical WEP2 – Horizontal WEP3 – Lower land WEP4 – Upper Land WEP5 – Open Land WEP6 – Agriculture land

Table 2: Nomenclature

The weights of the criterion are calculated using Analytical Hierarchy Process (AHP). The structure of the hierarchy is given below

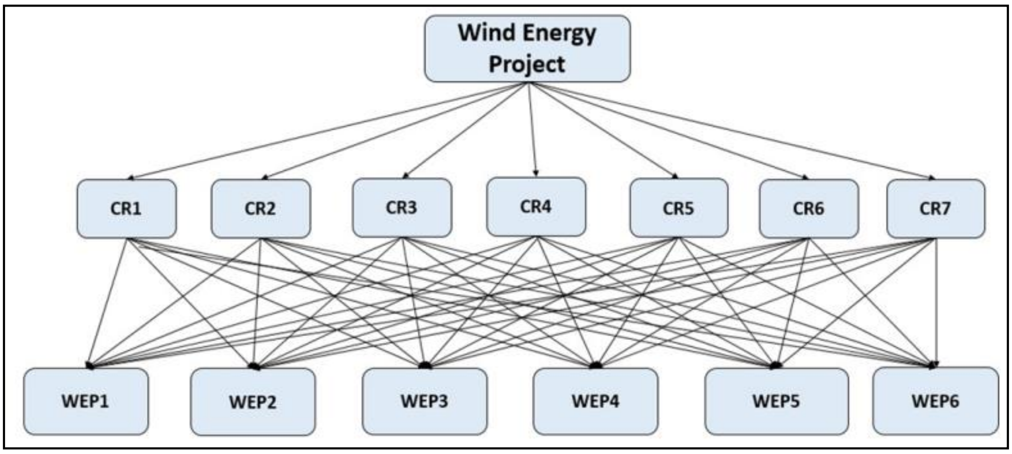

Figure 2: Decision Hierarchy

As indicated in the fig (2) above, create a hierarchy with the best Wind mill project (Goal) at the top, the criteria (CR) at the second level, and the projects (WEP) at the third level. This case study considers seven criteria and six alternatives (windmills).

III PROPOSED ALGORITHMS

Step1: A series of pair-wise comparisons are carried out among the elements at the same level in the next higher level using Saaty's nine-point scale which is listed below, and judgment matrices are formulated for all evaluation criteria. The pair-wise comparisons of various criteria generated say matrix A.

Step2: The next step involves the comparison matrix A and transforming it into matrix B, for calculating average

$$b_{jk}=\frac{a_{jk}}{\sum_{i=1}^{m} a_{ik}}$$

Where i,j,k=1,2,3,…n

Step3: Then calculate eigenvector w=wj, which is known as the criteria weight vector w

$$W_j = \frac{\sum_{i=1}^{m} b_{j1}}{m}$$

Where i,j=1,2,3,…n

Step4: The pair wise comparisons of various criteria generated at step 4, Based on the calculated Value the maximum eigenvalues are calculates using the below equation

$$\lambda_{max} = \frac{1}{m}\sum_{j=1}^{m} \frac{(AW)_j}{W_j}$$

Where j=1,2,3,…n

Step5: The consistency of the matrix of order m is evaluated. The AHP incorporates an effective technique for checking the consistency of the evaluations when building each of the pair wise comparison matrices involved in the process. For checking the consistency of the matrix, calculate the Consistency Index (CI) as

$$CI=\frac{\lambda_{max}-n}{n-1}$$

Step6: Consistency ratio (CR), which can be calculated as the ratio of the consistency index (CI) of the matrix to the consistency index of a random index (RI). The value of RI takes from the Consistency indices for a randomly generated matrix.

$$CR=\frac{CI}{RI}$$

Step 7: The assessment matrix has been standardized. To compute it, we must first select the advantageous and unfavourable criteria. Criteria requiring a lower value are considered non-beneficial, whilst requirements requiring a higher value are considered helpful.

$$for\ benificial\ criteria\ Rij = \frac{(x_{ij}) - max(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}$$

$$for\ non-beneficial\ criteria\ Rij = \frac{max(x_{ij}) - (x_{ij})}{\max(x_{ij}) - \min(x_{ij})}$$

Step 8: Determine the evaluative difference between the ith and other alternatives.

Step 9: Determine the preference function, P_j(a,b).

P_j(a,b) = 0 if the evaluative difference < 0 ($R_{aj} < R_{bj}$)

P_j(a,b) = R_{aj} - R_{bj} if the evaluative difference < 0 ($R_{aj} > R_{bj}$)

Step 10: Determine the aggregated preference function π (a, b). Divide the total of the weights by the sum of the values in the row. When comparing the identical alternatives, no value is awarded; otherwise, the aggregated preference function value is supplied.

$$\prod(a,b) = \frac{\sum_{j=1}^{n} w_j p_j(a,b)}{\sum_{j=1}^{n} w_j}$$

Step 11: Calculate the leaving (positive) and the entering (negative) outrank flows.

$$for\ leaving\ \varphi + = \frac{1}{n-1} \sum_{b=n}^{n} \prod(a,b)$$

$$for\ leaving\ \varphi - = \frac{1}{n-1} \sum_{b=1}^{n} \prod(b,a)$$

Step 12: Determining the net outflow rating of each option.

$$(a) = \varphi^{+}(a) - \varphi^{-}(a)$$

Step 1: The construction of a pair-wise comparison matrix is necessary for this step. The grid size for this is 7x7. This matrix solely relied on a significance scale from 1 to 9. From person to person, this will differ.

Criteria's	CR1	CR2	CR3	CR4	CR5	CR6	CR7
CR1	1	0.5	0.5	0.333	0.333	0.5	0.25
CR2	2	1	0.25	0.333	0.5	0.333	0.333
CR3	2	4	1	0.333	0.333	0.333	0.25
CR4	3	3	3	1	2	0.5	0.333
CR5	3	2	3	0.5	1	0.5	0.333
CR6	2	3	3	2	2	1	0.5
CR7	4	3	4	3	2	2	1

Table 3: Pair-wise comparison matrix

Following that, a normalized pair wise comparison matrix must be generated

Criteria's	CR1	CR2	CR3	CR4	CR5	CR6	CR7
CR1	0.0588	0.0303	0.0339	0.0444	0.0408	0.0968	0.0834
CR2	0.1176	0.0606	0.0169	0.0444	0.0612	0.0645	0.1110
CR3	0.1176	0.2424	0.0678	0.0444	0.0408	0.0645	0.0834
CR4	0.1765	0.1818	0.2034	0.1334	0.2449	0.0968	0.1110
CR5	0.1765	0.1212	0.2034	0.0667	0.1225	0.0968	0.1110
CR6	0.1176	0.1818	0.2034	0.2667	0.2449	0.1936	0.1667
CR7	0.2353	0.1818	0.2712	0.4001	0.2449	0.3871	0.3334

Table 4: Pair-wise normalized matrix

Step 3:

The consistency matrix is being computed. The weighted total value is then determined by adding all of the values in the given row. Following that, for each row, a weighted total value to criterion weight ratio must be determined.

Criteria's	CT1	CT2	CT3	CT4	CT5	CT6	CT7
CR1	0.0555	0.0340	0.0472	0.0546	0.0427	0.0982	0.0734
CR2	0.1110	0.0680	0.0236	0.0546	0.0641	0.0654	0.0977
CR3	0.1110	0.2722	0.0944	0.0546	0.0427	0.0654	0.0734
CR4	0.1664	0.2041	0.2832	0.1640	0.2566	0.0982	0.0977
CR5	0.1664	0.1361	0.2832	0.0820	0.1283	0.0982	0.0977
CR6	0.1110	0.2041	0.2832	0.3279	0.2566	0.1964	0.1467
CR7	0.2219	0.2041	0.3776	0.4919	0.2566	0.3928	0.2934

Table 5: Consistency Ratio Calculation

Step4:

The average of these values is used to determine lambda max. The consistency index is then computed. Using the below formula.

$$\lambda = \frac{Weighted\ sum\ value}{Criteria\ weight}$$

Criteria	Weighted Sum Value	Criteria Weights	λ
CR1	0.40558	0.05548	7.310442
CR2	0.48446	0.068048	7.119419
CR3	0.71363	0.094411	7.558847
CR4	1.27026	0.163967	7.747058
CR5	0.99194	0.12829	7.732029
CR6	1.52595	0.196396	7.769764
CR7	2.23839	0.293409	7.628902

Table 6: Calculation of λ

Maximum Value = Average Value of λ= 7.552352

Step5: Consistency index (C.I) $=\frac{\lambda_{max}-n}{n-1}$

Consistency index (C.I) =0.092059,

n = 7, where n is the number of criteria

Step6: Consistency Ratio $=\frac{C.I}{R.I}$, (Where R.I=1.32)

Consistency Ratio = 0.069741< 0.10

the criterion weights have been defined, the PROMETHEE II technique will be used to rank wind mill projects.

Criteria	Weights
CR1 - Wind power (MW)	0.05548
CR2 - Hub height (m)	0.068048
CR3 – Distance (m)	0.094411
CR4 – Cost (crores)	0.163967
CR5 – CO_2 (million tonnes reduced)	0.12829
CR6 - Wind speed (m/s)	0.196396
CR7 - Blade height (m)	0.293409

Table 7: Weights of every criteria

Step 7:

The assessment matrix has been standardized. To compute it, we must first select the advantageous and unfavourable criteria. Criteria requiring a lower value are considered non-beneficial, whilst requirements requiring a higher value are considered helpful.

Criteria	CR1	CR2	CR3	CR4	CR5	CR6	CR7
Beneficial / Non-beneficial	Benficial	Benficial	Non Benficial	Non Benficial	Benficial	Benficial	Non Benficial
Weight (W_j)	**0.05548**	**0.068048**	**0.094411**	**0.16397**	**0.12829**	**0.196396**	**0.29341**

Table 8: AHP values for the Beneficial and non-beneficial criteria

Criteria / Project	CR1	CR2	CR3	CR4	CR5	CR6	CR7
WEP1	1064	120	1700	14500	0.21	15.3	70
WEP2	1500	120	1900	10500	4.2	19	60
WEP3	650	120	2000	8000	1.75	5	80
WEP4	150	120	1500	6000	1	2	50
WEP5	56.1	120	2500	4000	1.29	5	70
WEP6	6	78	2600	2000	0.9	11	30

Table 9: A matrix of choices for projects

Criteria's	CR1	CR2	CR3	CR4	CR5	CR6	CR7
Max Xij	1500	120	2600	14500	4.2	19	80
MinXij	6	78	1500	2000	0.21	2	30

Table 10: The highest and lowest values for each individual criterion

Criteria / Project	CR1	CR2	CR3	CR4	CR5	CR6	CR7
WEP1	0.708166	1	0.818182	0	0	0.782353	0.2
WEP2	1	1	0.636364	0.32	1	1	0.4
WEP3	0.431058	1	0.545455	0.52	0.38596	0.176471	0
WEP4	0.096386	1	1	0.68	0.19799	0	0.6
WEP5	0.033534	1	0.090909	0.84	0.27068	0.176471	0.2
WEP6	0	0	0	1	0.17293	0.529412	1

Table 11: Normalization matrix for alternatives

Step 8: Determine the evaluative difference between the i^{th} and other alternatives.

Criteria Project	CR1	CR2	CR3	CR4	CR5	CR6	CR7
WEP1	-0.291834	0	0.181818	-0.32	-1	-0.21765	-0.2
	0.277108	0	0.272727	-0.52	-0.386	0.605882	0.2
	0.61178	0	-0.18182	-0.68	-0.198	0.782353	-0.4
	0.674632	0	0.727273	-0.84	-0.2707	0.605882	0
	0.708166	1	0.818182	-1	-0.1729	0.252941	-0.8
WEP2	0.291834	0	-0.18182	0.32	1	0.217647	0.2
	0.568942	0	0.090909	-0.2	0.61404	0.823529	0.4
	0.903614	0	-0.36364	-0.36	0.80201	1	-0.2
	0.966466	0	0.545455	-0.52	0.72932	0.823529	0.2
	1	1	0.636364	-0.68	0.82707	0.470588	-0.6
WEP3	-0.277108	0	0.181818	1	0.38596	-0.60588	-0.2
	-0.568942	0	0.363636	0.68	-0.614	-0.82353	-0.4
	0.334672	0	0	0.32	0.18797	0.176471	-0.6
	0.397523	0	0.909091	0.16	0.11529	0	-0.2
	0.431058	1	1	0	0.21303	-0.35294	-1
WEP4	-0.61178	0	0.181818	1	0.19799	-0.78235	0.4
	-0.903614	0	0.363636	0.68	-0.802	-1	0.2
	-0.334672	0	0.454545	0.48	-0.188	-0.17647	0.6
	0.062851	0	0.909091	-0.16	-0.0727	-0.17647	0.4
	0.096386	1	1	-0.32	0.02506	-0.52941	-0.4
WEP5	-0.674632	0	-0.72727	0.84	0.27068	-0.60588	0
	-0.966466	0	-0.54545	0.52	-0.7293	-0.82353	-0.2
	-0.397523	0	-0.45455	0.32	-0.1153	0	0.2
	-0.062851	0	-0.90909	0.16	0.07268	0.176471	-0.4
	0.033534	0.033	0.033534	-0.966	0.09774	-0.35294	-0.8
WEP6	-0.708166	-1	-0.81818	1	0.17293	-0.25294	0.8
	-1	-1	-0.63636	0.68	-0.8271	-0.47059	0.6
	-0.431058	-1	-0.54545	0.48	-0.213	0.352941	1
	-0.096386	-1	-1	0.32	-0.0251	0.529412	0.4
	-0.033534	-1	-0.09091	0.16	-0.0977	0.352941	0.8

Table 12: Comparative evaluation matrix

Step 9: Determine the preference function, pj(a,b).

riteria roject	CR1	CR2	CR3	CR4	CR5	CR6	CR7
WEP1	0	0	0.181818	0	0	0	0
	0.277108	0	0.272727	0	0	0.605882	0.2
	0.61178	0	0	0	0	0.782353	0
	0.674632	0	0.727273	0	0	0.605882	0
	0.708166	1	0.818182	0	0	0.252941	0
WEP2	0.291834	0	0	0.32	1	0.217647	0.2
	0.568942	0	0.090909	0	0.61404	0.823529	0.4
	0.903614	0	0	0	0.80201	1	0
	0.966466	0	0.545455	0	0.72932	0.823529	0.2
	1	1	0.636364	0	0.82707	0.470588	0
WEP3	0	0	0.181818	1	0.38596	0	0
	0	0	0.363636	0.68	0	0	0
	0.334672	0	0	0.32	0.18797	0.176471	0
	0.397523	0	0.909091	0.16	0.11529	0	0
	0.431058	1	1	0	0.21303	0	0
WEP4	0	0	0.181818	1	0.19799	0	0.4
	0	0	0.363636	0.68	0	0	0.2
	0	0	0.454545	0.48	0	0	0.6
	0.062851	0	0.909091	0	0	0	0.4
	0.096386	1	1	0	0.02506	0	0
WEP5	0	0	0	0.84	0.27068	0	0
	0	0	0	0.52	0	0	0
	0	0	0	0.32	0	0	0.2
	0	0	0	0.16	0.07268	0.176471	0
	0.033534	0.0335	0.033534	0	0.09774	0	0
WEP6	0	0	0	1	0.17293	0	0.8
	0	0	0	0.68	0.17293	0	0.6
	0	0	0	0.48	0	0.529412	0.4
	0	0	0	0.32	0	0.352941	1
	0	0	0	0.16	0	0.352941	0.8

Table 13: Matrix with preference functions

Step 10: Determine the aggregated preference function π (a,b). Divide the total of the weights by the sum of the values in the row. When comparing the identical alternatives, no value is awarded; otherwise, the aggregated preference function value is supplied.

riteria roject	CR1	CR2	CR3	CR4	CR5	CR6	CR7	SUM
WEP1	0	0	0.017166	0	0	0	0	**0.017**
	0.015374	0	0.025748	0	0	0.118993	0.05868	**0.219**
	0.033942	0	0	0	0	0.153651	0	**0.188**
	0.037429	0	0.068663	0	0	0.118993	0	**0.225**
	0.039289	0.068048	0.077245	0	0	0.049677	0	**0.234**
WEP2	0.016191	0	0	0.05247	0.12829	0.042745	0.05868	**0.298**
	0.031565	0	0.008583	0	0.07877	0.161738	0.11736	**0.398**
	0.050133	0	0	0	0.10289	0.196396	0	**0.349**
	0.05362	0	0.051497	0	0.09356	0.161738	0.05868	**0.419**
	0.05548	0.068048	0.06008	0	0.1061	0.092422	0	**0.382**
WEP3	0	0	0.017166	0.16397	0.04952	0	0	**0.231**
	0	0	0.034331	0.1115	0	0	0	**0.146**
	0.018568	0	0	0.05247	0.02411	0.034658	0	**0.13**
	0.022055	0	0.085828	0.02623	0.01479	0	0	**0.149**
	0.023915	0.068048	0.094411	0	0.02733	0	0	**0.214**
WEP4	0	0	0.017166	0.16397	0.0254	0	0.11736	**0.324**
	0	0	0.034331	0.1115	0	0	0.05868	**0.205**
	0	0	0.042914	0.0787	0	0	0.17605	**0.298**
	0.003487	0	0.085828	0	0	0	0	**0.2.7**
	0.005347	0.068048	0.094411	0	0.00322	0	0	**0.171**
WEP5	0	0	0	0.13773	0.03473	0	0	**0.172**
	0	0	0	0.08526	0	0	0	**0.085**
	0	0	0	0.05247	0	0	0.05868	**0.111**
	0	0	0.	0.02623	0.00932	0.034658	0	**0.07**
	0.00186	0.002282	0.003166	0	0.01254	0	0	**0.02**
WEP6	0	0	0	0.16397	0.02219	0	0.23473	**0.421**
	0	0	0	0.1115	0	0	0.17605	**0.288**
	0	0	0	0.0787	0	0.069316	0.29341	**0.441**
	0	0	0	0.05247	0	0.103974	0.11736	**0.274**
	0	0	0	0.02623	0	0.069316	0.23473	**0.33**

Table 14: Matrix I of the aggregated preference function

Aggregated preference function	WEP1	WEP2	WEP3	WEP4	WEP5	WEP6
WEP1	--	0.017166	0.218797	0.18759	0.22508	0.234259
WEP2	0.298377	--	0.398024	0.34942	0.4191	0.382134
WEP3	0.230648	0.145829	--	0.12981	0.14891	0.213704
WEP4	0.323897	0.204511	0.297664	--	0.20668	0.171022
WEP5	0.172457	0.085263	0.111151	0.07022	--	0.019848
WEP6	0.42088	0.287543	0.441429	0.27381	0.33028	--

Table 15: Matrix-II of the aggregated preference function

Step 11: Compute the outrank flows that are leaving (positive) and entering (negative).

Aggregated preference function	WEP1	WEP2	WEP3	WEP4	WEP5	WEP6	**Leaving flow α+(a)**
WEP1		0.017166	0.218797	0.18759	0.22508	0.234259	**0.17658**
WEP2	0.298377		0.398024	0.34942	0.41910	0.382134	**0.36941**
WEP3	0.230648	0.145829		0.12981	0.14891	0.213704	**0.17378**
WEP4	0.323897	0.204511	0.297664		0.20668	0.171022	**0.24075**
WEP5	0.172457	0.085263	0.111151	0.07022		0.019848	**0.09179**
WEP6	0.420881	0.287534	0.441429	0.27381	0.33028		**0.35079**
Entering flow α-	**0.289252**	**0.148062**	**0.293413**	**0.20217**	**0.26601**	**0.204193**	

Table 16: Positive and Negative outrank flows

Step 12: Determining the net outflow rating of each option.

Aggregated preference function	**α(a)**	**Rank**
WEP1-Jaisalmer wind park, Rajasthan	-0.11267	4
WEP2-Muppandal wind farm, Kanyakumari	***0.221349***	***1***
WEP3-Brahmanvel wind farm, Maharashtra	-0.11963	5
WEP4-Damanjodi wind farm, Odisha	0.038585	3
WEP5-Tuppadahalli wind farm, Karnataka	-0.17422	6
WEP6-Tirupathi windmill, Tirupathi	0.146594	2

Table 17: Ranking outflow for each alternative, netted out

Using the net out ranking flow figures, determine the rank of each choice. The higher the rank, the greater the value.

IV. RESULTS AND DISCUSSION

Eventually, among the six wind farms, Horizontal (WEP2) project scored highest and Open Land (WEP5) project ranked lowest in the above table, and the order of preference is as follows: WEP2 (0.221349)>WEP6 (0.146594)>WEP4 (0.038585)>WEP1 (-0.11267)>WEP3 (-0.11963)> WEP5 (-0.11963) (-0.17422). WEP2 has the highest net out ranking flow of 0.221349 among the six projects depicted in figure 3. PROMETHEE II, one of the MCDM approaches, was used to complete the proposed methodology for picking the best wind farm among six projects located around India.

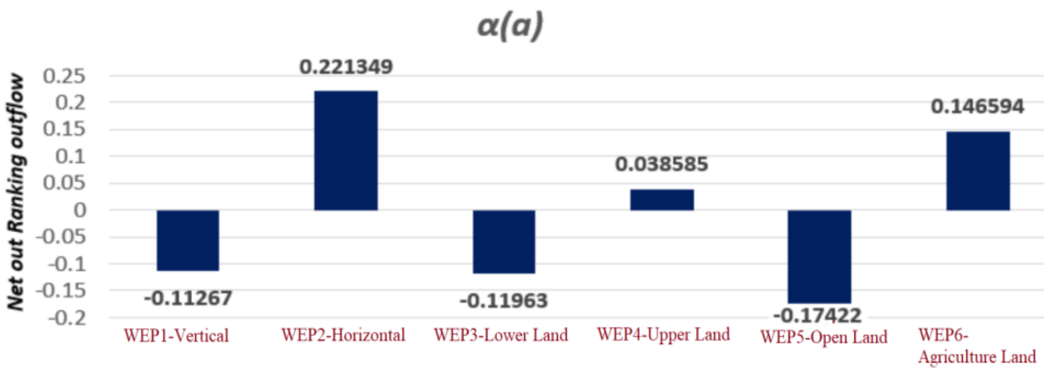

Figure 3: Several wind energy project histograms

After calculating the performance score based on seven factors, the Horizontal and Agricultural Land achieved net out ranking values of 0.221349 and 0.146594, respectively. According to the data, Horizontal is selected as the best wind power project among those studied, with the greatest net out ranking value, due to its large producing capacity of 1500MW, high wind speed of 19m/s, and ability to save the environment from CO2 (4.2 million tonnes reduced).

After calculating the performance score based on seven factors, the Horizontal and Agricultural Land achieved net out ranking values of 0.221349 and 0.146594, respectively. According to the data, Horizontal is selected as the best wind power project among those studied, with the greatest net out ranking value, due to its large producing capacity of 1500MW, high wind speed of 19m/s, and ability to save the environment from CO2 (4.2 million tonnes reduced).

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