A PROMETHEE based multi criteria decision making analysis for selection of optimum site location for wind energy project

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Abstract. This paper presents a PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method based on AHP (Analytical Hierarchy Process) is applied to the selection of optimum site location for Wind energy projects. Our case study tried to find out the selection of best site for the wind energy project in India. For this study authors have chosen six wind energy projects which are located across in India. Wind power, Hub height, Distance, Cost, CO₂, Wind speed and Blade height are the seven criteria had taken for the selection of best location. AHP is integrated with PROMETHEE to meet the objective of this study. Firstly, the weights of each criterion are to determine using Analytical Hierarchy. These weights will be used in PROMETHEE II method to select the best project. A case study is performed to exhibit the application of the methods was conducted to evaluate six types of wind power projects. The AHP-PROMETHEE II result showed that the Muppandal wind farm, Kanyakumari is the best wind power project among the six projects.

1. Introduction
Nowadays, ozone utilization, growing overall ordinary temperature, natural change, different sorts of sullying, and high dependence on oil based goods are some the huge issues going up against mankind. Unmistakably wellsprings of coal, oil, and gas will at long last vanish inside a sensible time period. Thusly, the extended use of great and reasonable force sources is one of the measures that many made countries have taken in continuous decades to deal with these issues to some degree. The headway of feasible force source development and its going with benefits, for instance, diminished pollution, wealth, and immutability have caused such an essentialness, especially wind imperativeness, to end up being monetarily sensible and to be seen well by all authorities in regards to this issue. Wind, as other sustainable power sources, is geologically across the board and is quite often accessible; nonetheless, it is additionally scattered and decentralized and has a fluctuating and irregular nature.

The paper is organized as follows: after the introduction consists of literature survey, Section 2 presents the methodology with mathematical formulation of the new MCDM method and the basic steps of the AHP and PROMETHEE II presents results with an application of the AHP and PROMETHEE II calculations. The final section (Section 3&4) presents the results and conclusion respectively. The aim of this paper is to choose the best project Windmill in India. Here six Windmills have been chosen as projects and seven criteria’s for selection.
Analytical Hierarchy Process technique is utilized to discover the models weight’s those will be utilized in TOPSIS calculation to rank the bicycles from execution scores all things considered. The proposed system for the determination of best bicycle among ten options has done utilizing MCDM strategy [1]. Akram M et.al., had done research on a version of the PROMETHEE technique that encompasses multipolar checks of the performance of every opportunity (relative to the applicable criteria) [2]. Bottero M et.al., proposes a study of unique multi-methodological approach, which mixes SWOT evaluation, Stakeholders analysis and PROMETHEE technique for the assessment of alternative renewal techniques of a city location in Northern Italy [3]. Sapkota M et.al., evaluates some of hybrid water supply situations the use of a case observes based on the Northern boom region of Melbourne, Australia. It uses MCDM technique for Enrichment opinions (PROMETHEE) and Geometrical analysis for Interactive decision aid (GAIA) [4]. Their examples of utilization contrast notably between and among created and creating nations and this influences the wellbeing difficulties and portability openings that they speak to. Pamučar, D et al., (2015) indicated that the TOPSIS, MOORA, SAW, COPRAS and VIKOR techniques don’t meet at least one conditions set, but the MABAC strategy demonstrated soundness in its answers. Through the exploration introduced right now, is indicated that the new MABAC technique for MCDM is a helpful and solid apparatus for rational decision-making [5]. Sustainable power source is developing as an answer for a sustainable, environmentally well-disposed and long haul, savvy wellspring of vitality for what’s to come. Sustainable power source choices are equipped for supplanting ordinary wellsprings of vitality in a large portion of their applications at serious long haul costs [6, 7].

Ivanova et al. surveyed the attainability of wind power plant development in an electric force framework utilizing a progressive multi-criteria approach [8]. Charnes, A et al., (1978) proposed a nonlinear (nonconvex) programming model which gives another meaning of effectiveness for use in assessing exercises of not-revenue driven substances taking an interest openly programs [9]. Haworth, N et al., (2012) discussed about PTWs and will keep on developing as they assume a significant job in both vehicle and entertainment over the world [10]. Wind vitality, sun based photovoltaic, sun oriented warm, and biomass vitality were utilized as choices. Martin et al. (2013) introduced a technique to assess various drifting help structure designs, for seaward wind turbines sent in profound waters [11]. Datta et al. (2014) recognized the best islanding recognition strategy for a sunlight based photovoltaic framework by utilizing TOPSIS alongside other MCDM strategies [12]. Kahraman et.al., (2010) executed a fuzzy MCDM method, in view of the AHP strategy, to locate the ideal among vitality strategies in Turkey [13].

2. Methodology and Analysis
2.1 Proposed Methodology for Optimum Solution
In order to find out the best wind power project out of 6 projects firstly estimate the criteria weights using Analytical Hierarchy Process (AHP). Using these criteria weights, next find out the rankings for all the projects using MCDM technique like PROMETHEE II. Finally, rank the projects based on their Net out ranking outflow or score. The data for various wind energy projects in India are collected from the internet source.

| Criteria          | Project                     | Wind power (MW) | Hub height (m) | Distance (m) | Cost (crores) | CO₂ (million tonnes reduced) | Wind speed (m/s) | Blade height (m) |
|-------------------|-----------------------------|-----------------|----------------|--------------|--------------|------------------------------|------------------|-----------------|
| Wind power        | Jaisalmer wind park, Rajasthan | 1064            | 120            | 1700         | 14500        | 0.21                         | 15.3             | 70              |
Muppandal wind farm, Kanyakumari | 1500 | 120 | 1900 | 10500 | 4.2 | 19 | 60
Brahmanvel wind farm, Maharashtra | 650 | 120 | 2000 | 8000 | 1.75 | 5 | 80
Damanjodi wind farm, Odisha | 150 | 120 | 1500 | 6000 | 1 | 2 | 50
Tuppadahalli wind farm, Karnataka | 56.1 | 120 | 2500 | 4000 | 1.29 | 5 | 70
Tirupathi windmill, Tirupathi | 6 | 78 | 2600 | 2000 | 0.9 | 11 | 30

| Criteria | Wind Energy Project |
|------------------|---------------------|
| CR1 - Wind power (Mega Watts) | WEP1 – Jaisalmer wind park, Rajasthan |
| CR2 - Hub height (meters) | WEP2 – Muppandal wind farm, Kanyakumari |
| CR3 – Distance (meters) | WEP3 – Brahmanvel wind farm, Maharashtra |
| CR4 – Cost (crores) | WEP4 – Damanjodi wind farm, Odisha |
| CR5 – CO₂ (million tonnes reduced) | WEP5 – Tuppadahalli wind farm, Karnataka |
| CR6 - Wind speed (meters/second) | WEP6 – Tirupathi windmill, Tirupathi |
| CR7 - Blade height (meters) | |

2.1.1. Analytical Hierarchy Process (AHP)
This method is used to calculate the weights of the criteria. It mainly involves 3 steps.

Step 1:
Firstly develop a hierarchal structure shown in the below figure with the best Wind energy project (Goal) at the top level, the criteria (CR) at the second level and the projects (WEP) at third level.
In this case study, considering 6 Projects i.e., windmills and 7 Criteria’s.

Figure 1: Decision Hierarchy
Step 2:
This step involves developing a pair wise comparison matrix.
Which is having a matrix size of 7*7. This matrix was completely depending upon scale of importance
given from 1 to 9. It will be variable for person to person.

**Table 3: Comparison of pair-wise matrix**

| 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   |

After that normalized pair wise comparison matrix has to be created.

**Table 4: Normalised Pair-wise matrix**

| 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 |

Step 3:
Calculating the consistency matrix.
Then weighted sum value is calculated by adding all the values in the particular row. After that ratio of
weighted sum value to the criteria weight has to be calculated for each row.

**Table 5: Calculating the Consistency**

| 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 |

Now, lambda max is calculated by taking the average of these values. Then consistency index is to be calculated.

\[ \lambda = \text{Weighted Sum Value} / \text{Criteria Weight} \] (1)
Table 6: Calculation of $\lambda$

| Criteria  | Weighted Sum Value | Criteria Weights | $\lambda$ |
|-----------|---------------------|------------------|-----------|
| 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 |

$\lambda_{max} = \text{Average Value of } \lambda = 7.552352$

Consistency index (C.I) = $(\lambda_{max}-n)/(n-1)$ (2)

Consistency index (C.I) = 0.092059

$n = \text{number of criteria} = 7$

Table 7: Random Index

| No | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|----|----|----|----|----|----|----|----|----|----|----|
| RCI| 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Consistency Ratio = C.I/ R.C.I (3)

Consistency Ratio = 0.069741 $\times$ 0.10

Since CR equal to 0.069741 i.e., 6.97% error only which is less than 10% then considered the criteria weights from Analytical Hierarchy Process. If the error is more than 10%, then repeat the entire AHP steps until the error less than 10%.

Once the criteria weights are finalized, it will be used in PROMETHEE II method for ranking the wind power projects.

Table 8: Weights of each criteria

| 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 |

2.1.2. PROMETHEE II Method

In PROMETHEE, many sub methods are there. Out of which PROMETHEE II method had chosen. PROMETHEE is similar method like ELECTRE which is also having many iterations as well as one of the outranking method [14].

Now, dealing with the selection of best wind power project out of 6 projects. Criteria’s are Wind power, Hub height, Distance, Cost, CO$_2$, Wind speed and Blade height.
Figure 2: Step by Step procedure for selection of wind energy project

The procedure of PROMETHEE II method is as follows:

**Step 1:**
Normalization of evaluation matrix. To calculate it we have to select the beneficial and non beneficial criteria. For the criteria that requires lower value is considered as non beneficial criteria and for the criteria that requires higher value is considered as beneficial criteria.

**Table 9:** Beneficial and Non-beneficial criterion values calculated using AHP

| Criteria | CR1  | CR2  | CR3  | CR4  | CR5  | CR6  | CR7  |
|----------|------|------|------|------|------|------|------|
| Weight   | 0.05548 | 0.068048 | 0.094411 | 0.16397 | 0.12829 | 0.196396 | 0.29341 |

**Table 10:** Decision Matrix for projects

| Project | Criteria | 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 11:** Maximum and Minimum values of individual criteria’s

| 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   |
for beneficial criteria  \( R_{ij} = \frac{x_{ij} - \max(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \)  

(4)

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

(5)

**Table 12: Normalization Matrix for alternatives**

| Criteria | 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 |

**Step 2:**

Calculate the evaluative difference between i\(^{th}\) alternative with respect to other alternative.

**Table 13: Evaluative difference matrix**

| Criteria | 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 |
Step 3: Calculate the preference function, \( p_j(a,b) \).

\[
p_j(a,b) = 0 \text{ if the evaluative difference } < 0 \quad (R_{aj} \leq R_{bj}) \quad (6)
\]
\[
p_j(a,b) = R_{aj} - R_{bj} \text{ if the evaluative difference } < 0 \quad (R_{aj} > R_{bj}) \quad (7)
\]

**Table 14: Preference function matrix**

| Criteria | CR1     | CR2     | CR3     | CR4     | CR5     | CR6     | CR7     |
|----------|---------|---------|---------|---------|---------|---------|---------|
| Project  | CR1     | CR2     | CR3     | CR4     | CR5     | CR6     | CR7     |
| WEP1     | 0       | 0.277108| 0.181818| 0       | 0       | 0.605882| 0.2     |
|          | 0.61178 | 0       | 0.272727| 0       | 0       | 0       | 0.782353|
|          | 0.674632| 0       | 0.727273| 0       | 0       | 0       | 0.605882|
|          | 0.708166| 1       | 0.818182| 0       | 0       | 0       | 0.252941|
| WEP2     | 0.291834| 0       | 0       | 0.32    | 1       | 0.217647| 0.2     |
|          | 0.568942| 0       | 0.090909| 0       | 0       | 0.61404 | 0.823529|
|          | 0.903614| 0       | 0       | 0       | 0.80201 | 1       | 0       |
|          | 0.966466| 0       | 0.545455| 0       | 0       | 0.72932 | 0.823529|
|          | 1       | 1       | 0.636364| 0       | 0       | 0.82707 | 0.470588|
| 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       | 0.909091| 0.16    | 0.11529 | 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       |
|          | 0.062851| 0       | 0       | 0.909091| 0       | 0       | 0.4     |
Step 4: Calculate the aggregated preference function, $\pi(a,b)$. Add all the values in the row and divide it by the sum of weights. When same alternative is compared no value is assigned otherwise aggregated preference function value is given.

$$\pi(a, b) = \frac{\sum_{j=1}^{n} w_j p_j(a,b)}{\sum_{j=1}^{n} w_j} \quad (8)$$

| Criteria | CR1 | CR2 | CR3 | CR4 | CR5 | CR6 | CR7 | SUM   |
|----------|-----|-----|-----|-----|-----|-----|-----|-------|
| Project  |     |     |     |     |     |     |     |       |
| 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 |
|          | 0.035165 | 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   | 0.034331 | 0.1115 | 0   | 0.115 | 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 |
| SUM      | 0   | 0   | 0.017166 | 0.16397 | 0.0254 | 0   | 0   | 0.11736 | 0.324 |
Table 16: Aggregated preference function matrix-II

| 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 | --     |

Step 5:
Calculate the leaving (positive) and the entering (negative) outrank flows.

\[
f(\text{leaving}) = \kappa^+ = \frac{1}{n-1} \sum_{b=1}^{n} \pi(a, b)
\]

\[
f(\text{entering}) = \kappa^- = \frac{1}{n-1} \sum_{b=1}^{n} \pi(b, a)
\]

Table 17: Leaving (positive) and Entering (negative) outrank flows

| Aggregated preference function | WEP1 | WEP2 | WEP3 | WEP4 | WEP5 | WEP6 | Leaving flow \( \alpha^+(a) \) |
|--------------------------------|------|------|------|------|------|------|------------------|
| 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 | --     |
**Step 6:**
Calculating the net out ranking outflow for each alternative.

\[ \varphi(a) = \varphi^+(a) - \varphi^-(a) \]  

(Table 18: Net out ranking outflow for each alternative)

| Aggregated preference function                  | \(a(a)\) | Rank |
|-----------------------------------------------|----------|------|
| WEP1-Jaisalmer wind park, Rajasthan           | -0.11267| 4    |
| WEP2-Muppadal 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    |

**Step 7:**
Determine the rank of each alternative based on the values of net out ranking flow. Higher the value will have the rank 1.

3. Results and Discussion

Finally, from the above table, Muppadal wind farm, Kanyakumari (WEP2) ranked the best and Tuppadahalli wind farm, Karnataka (WEP5) project ranked least among six windfarms and the order of preference is as follows:

**WEP2(0.221349) > WEP6(0.146594) > WEP4(0.038585) > WEP1(-0.11267) > WEP3(-0.11963) > WEP5(-0.17422)**.

Here WEP2 is having a net out ranking flow of 0.221349 which is the best score among six projects which is shown in fig. 3. The proposed methodology for the selection of best windfarm among six projects which are located in different places of India has done using one of the MCDM technique PROMETHEE II.

![Figure 3: Histogram of various wind energy projects](image-url)
After finding the performance score using seven criteria’s, it is observed that the Muppandal wind farm, Kanyakumari and Tirupathi windmill, Tirupathi obtained the net out ranking values are 0.221349 and 0.146594 respectively. From the results it is observed Muppandal wind farm, Kanyakumari is identified as the best wind power project among the considered ones which has the best net out ranking value since it is having high generating capacity of 1500MW, high wind speed of 19m/s and it is saving the environment from CO$_2$ (4.2 million tonnes reduced).

4. Conclusions
This paper shows how the Analytical Hierarchy Process together with PROMETHEE II technique is used for selecting the optimum site location for wind energy projects and for a given commercial application in order to lessen the expenditure in future over a time frame. For evaluating six projects from different locations in India, seven criteria’s had chosen. Hence, explores the usage of PROMETHEE II technique in locating an optimum area selection problem and the outcomes obtained can be precious to the decision maker in framing the region choice techniques. It reduces the difficulty of choosing the best one among many for decision makers and permits them to rank the candidate alternatives more effectively. This method provide the solution set however additionally ranks all of the alternatives in a descending order.

The subsequent conclusions are summarized:

- Multi criteria decision making analysis indicates that wind energy project 2 (Muppandal wind farm, Kanyakumari) with score 0.221349 is the most preferred project and wind energy project 6 (Tirupathi windmill, Tirupathi) with score 0.146594 ranked second.
- With the same evaluation wind energy project 5 (Tuppadahalli wind farm, Karnataka) with score -0.17422 is the least preferred project out of Six alternatives.

Acknowledgments
Authors of this paper are whole heartedly thankful to all the colleagues of our organisation who supported us in every way, we would like to thank who supported us directly or indirectly for this work to make it happened.

References
[1] Manoj V, Swathi A and Tejeswara Rao V 2020 Journal of Critical Reviews 7 941-47
[2] Akram M and Alcantud J C R 2020 Mathematical and Computational Applications 25 1-26
[3] Bottero M, D’Alpaos C and Oppio A 2018 Advances in Operations Research 2018 1-12
[4] Sapkota M, Arora M, Malano H, Sharma A and Moglia M 2018 Water 10 1-15
[5] Pamučar D and Ćirović G 2015 Expert Systems with Applications 42 3016-28
[6] Aras H, Erdoğlu S and Koç E 2004 Renewable Energy 29 1383–92
[7] Lee S K, Mogib G and Kim J W 2009 Journal of Loss Prevention in the Process Industries 22 915–20
[8] Ivanova E Y, Voropai N I and Handschin E 2005 2005 IEEE Russia Power Tech 1–4
[9] Charnes A, Cooper W W and Rhodes E 1978 European journal of operational research 2 429-44
[10] Haworth N et al 2012 Accident Analysis & Prevention 44 12–18
[11] Martin H, Spano G, Küster J, Collu M and Kolios A 2013 Ships and Offshore Structures 8 477–87
[12] Datta A, Saha D, Ray A and Das P 2014 Solar Energy 110 519–32
[13] Kahraman C and Kayar I 2010 Expert Systems with Applications 37 6270–81
[14] Behzadian M, Kazemzadeh R, Albadvi A and Aghdasi M 2010 European Journal of Operational Research 200 198-215