SELECTING BEST LOCATION OF WIND PLANTS USING DEA AND TOPSIS APPROACH IN TURKISH CITIES

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ABSTRACT

Newly emerging renewable alternative energy resources are expected to take an increasing role in future energy scenarios. Environmental and technical benefits of wind energy have made it a promising alternative to conventional energy resources. Wind energy is a most ancient energy source and is the root material for almost all fossil and renewable types. Determining the priority of different locations has special importance for placing wind systems. Different factors may affect the selection of a suitable location for wind plants. These factors must be considered concurrently for optimum location identification of wind plants. This article presents an approach for location of wind plants by use of data envelopment analysis (DEA). Efficiency scores of 12 months are evaluated by using the modified technique for order preference by similarity to ideal solution (TOPSIS) method. The administrated approach was tested for 34 different cities in Turkey in different regions.

Keywords: Wind Plants, Data Envelopment Analysis (DEA), TOPSIS, Location

VERİ ZARFLAMA VE TOPSİS YAKLAŞIMLARI KULLANILARAK TÜRKİYE ŞEHİRLERİNDE RÜZGAR SANTRALLERİ İÇİN EN İYİ YER SEÇİMİ

ÖZET

Yenilenebilir alternatif enerji kaynaklarının gelecekteki enerji senaryolarında artan bir rol alması bekleniyor. Rüzgar enerjisinin çevre ve teknik faydaları konvansiyonel enerji kaynaklarına umut verici bir alternatif yapmaktadır. Rüzgar enerjisi en eski enerji kaynağıdır ve hemen hemen tüm fosil ve yenilenebilir türleri için kökenidir. Farklı yerlerde önceliğin belirlenmesi rüzgar sistemlerini kurmak için özel bir öneme sahiptir. Farklı faktörler rüzgar santralleri için uygun yer seçimini etkileyebilir. Bu faktörler, rüzgar santrallerinin optimum yer tespiti için eş zamanlı olarak kabul edilmelidir. Bu makale veri zarflama analizi (VZA) kullanılarak rüzgâr santrallerinin yer seçimi için bir yaklaşım sunuyor. 12 aylık etkinlik değerleri sıralanarak Türkiye için en uygun rüzgar santrali kurulacak yerin tespiti çok parametreli olarak irdelenmiştir.

Anahtar Kelimeler: Rüzgar santrali, Veri zarflama analizi, TOPSIS, Yer

1. INTRODUCTION

The negative effects of fossil fuels on the environment have forced many countries to use renewable energy sources. The technical benefits of wind energy have made it a promising alternative to conventional energy resources. Use of wind energy is rapidly developing in the world. These facilities have a great potential for supplying energy in remote regions. Determining the priority of different locations has special importance for the placement of wind systems.

Since the cost of investment in wind tribunes is high, feasibility studies prior to implementation of the projects is important. Problems encountered in the process of choosing the proper place for wind turbines, next to the examination of technical factors in overcoming the physical, economic, social, environmental and political factors, in order to support the decision making process of such complex applications, scientific studies are needed.

There are two basic criteria in the selection of the wind turbines. The first is efficiency of the area in terms of wind. The second fundamental fact is reduction of energy production cost to the minimum. The costs of land which the wind turbines are established in are one of the fundamental features in the second criterion. Credibility in availability and transportation and distance to the transformer centers, the topography, the land cover, the slope, the maintenance of turbines, the conservation areas, landslide areas and residential areas are significant factors about the area.

Deriving a model from the relationship between these factors create multiple relationships to determine the locations for wind power plants, will give investors the opportunity to pre-feasibility. Therefore, in this study, we will express a numerical example by use of Data Envelopment Analysis and the TOPSIS model and utilization of average wind speed, cost and distance to the power distribution networks which are the main factors of choosing suitable location for wind power plants in Turkey and by using the results of this example will help us in determination the most appropriate for the wind turbines in Turkey.

When analyzing the results obtained which are not directly reflected in the numerical size, the cost of energy which is the basic variable of second criterion must be considered in the assessment.

Papers on multi-criteria location problems were scarce until the past decade, when presenting and solving multi-criteria location problems have seen substantial growth and have opened new windows to location science indifferent areas of application [1].

To approach this issue, we have considered location selection of wind plants in this article. Determination of where to build wind observation stations is very important, and ideal location for such a region should in particular be able to represent the area well. Location problems are likely to have multiple objectives. The use of multi-criteria methods such as MCDM (Multiple Criteria Decision Making) and MADM (Multiple Attribute Decision Making) have become more common for considering different indicators for location optimization of such plants. In this article, DEA is used as a multi-criteria method for location of wind plants. This paper utilized 2010 wind speed data from 34 cities to assess the best location for wind plants. The obtained results of DEA efficiency scores in 12 months have been ordered by TOPSIS for selection of best place.

2. MATERIAL AND METHOD

2.1. Material

In this study we have applied DEA model for optimizing locations of wind plants in 34 cities in Turkey. Selected cities are those which have windy weather in Turkey, which has led to the wide coverage of the model.

For determining the best city/cities, 3 different parameters were used. These parameters were as follows:

Distance to power distribution networks (km)*:* As noted for establishing power plants, selection of regions with low distance to power distribution networks is a plus. The cost of electrification from the central power network is very high and hence supplying energy from local power generators that have low maintenance and operational costs is preferred. For this purpose, wind plants for windy locations are an excellent solution. Under this assumption, this parameter has an input structure.

Land cost (Turkish Lira (1TL ≈ 1.8$)): For wind plants, another aspect must be considered. Land is the underlying infrastructure for construction of each plant. This is more important for wind than for other plants because they considerably need more land than other methods of energy generation.

Average wind speed (km/h): Considering the output indicators of the DEA model, the most important factor for region selection of a wind plant is the regional wind rate. As slight changes in the location of a wind power plant through a particular region would not cause significant alterations in geographical factors, wind speed is considered as a level 1 indicator. In location feasibility studies of wind plants, higher wind speed will increase the possibility of selection of a particular location for wind plant establishment. This is why this indicator is considered an output indicator [1].

Cities used in the proposed model (which are the DMUs of level 2) and the quantity of related indicators are presented in Table1 and Fig.1. Land cost and distance to power distribution networks are presented in Table 1. Average wind speeds are presented in Table 2. The values of level 1 indicator distance to power distribution networks are based on the scores determined by the experts for each city. Therefore, this indicator has an increasing structure. The required data indicators which were used in the proposed model were gathered from the Turkish Meteorology web page (http:/www.mgm.gov.tr).

Table 1. Statistical values of the land cost, distance and wind speeds

	Lans cost (TL)	Distance (Km)	Wind Speed
MAX	80	165	7.94
MIN	13	5	1.26
Standard deviation	15.19	44.91	1.63

Figure1. Selected cities in Turkey

2.2. METHOD

2.2.1. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a nonparametric method for measuring the efficiency of a decision-making unit (DMU). Any group of entities that receives the same set of inputs and produces the same set of outputs could be designated as a DMU; it could be a group of people, a company, hospital, school, industry, or country. To determine the relative efficiency of each DMU in the group, DEA collapses inputs and outputs defined by the model into a ratio of a single meta-input and meta-output and uses linear programming methods to calculate the efficiency score for each DMU, where they obtained score is reflective of the performance [1-4].

Table 2. The values of average monthly wind speed in different cities (output)

Months→ / DMUs	1	2	3	4	5	6	7	8	9	10	11	12
ZONGULDAK	2.51	2.96	2.47	2.14	1.51	1.46	1.4	1.44	1.64	1.66	2.14	2.17
SINOP	3.11	3.64	3.39	3.08	3.38	2.91	2.61	2.78	2.51	2.86	2.3	3.21
SAMSUN	2.26	1.66	1.13	1.26	1.3	1.39	1.36	1.56	1.28	0.81	1.5	1.91
ORDU	1.26	1.39	1.48	1.37	1.51	1.56	1.68	1.77	1.53	1.15	1.12	1.19
GIRESUN	1.35	1.97	1.6	1.57	1.45	1.75	1.4	1.36	1.4	1.57	0.76	1.41
TRABZON	2.21	2.23	2.16	1.42	1.81	1.61	1.82	1.93	2.21	1.91	1.92	1.97
ARTVIN	1.6	1.73	1.91	1.93	1.74	2.2	2.81	2.6	2.39	1.58	1.66	1.91
ISTANBUL	7.94	7.39	7.44	7.07	5.5	5.29	5.94	6.4	7.6	7.21	7.4	8.84
EDIRNE	2.42	2.16	2.08	1.9	2.1	1.81	1.96	1.99	1.91	1.73	2.07	2.13
GOKCEADA	6.2	5.22	4.64	4	3.32	3.18	3.48	3.99	4.23	4.31	5.3	6.15
BALIKESIR	3.14	3.96	2.75	3.98	3.61	3.25	4.27	6.27	4.75	3.8	2.42	3.65
IZMIR	3.51	3.28	3.21	2.5	2.53	2.77	2.78	2.55	2.54	2.41	2.5	2.95
MANISA	1.72	1.59	1.45	1.57	1.32	1.43	2.04	1.87	1.57	1.42	1.12	1.22
AFYON	2.33	3.04	2.86	2.72	2.42	2.76	3.09	3.19	2.37	2.43	1.85	2.35
USAK	1.73	1.9	1.68	1.64	1.68	1.86	1.81	1.78	1.62	1.45	1.3	1.3
AKSARAY	2.91	3.38	2.94	2.8	2.2	2.26	2.51	2.56	2.31	2.12	2.5	2.36
DENIZLI	2.4	3.25	2.25	2.12	1.86	1.84	1.86	1.81	1.92	2.37	2.4	2.94
BURDUR	2.34	3.16	2.71	2.17	1.98	2	1.83	1.83	1.94	1.85	2.04	2.02
ISPARTA	1.42	1.72	1.33	1.22	1.23	1.43	1.46	1.16	1.25	1.26	1.19	1.26
DIYARBAKIR	2.55	1.62	1.99	2.03	2.16	2.44	2.23	2.13	1.5	1.84	1.4	1.56
HAKKARI	1.45	1.51	2.1	1.59	1.84	1.98	2.04	1.85	1.77	1.83	1.03	0.81
CANKIRI	1.33	1.46	1.47	1.38	1.39	1.46	1.46	1.33	1.23	1.29	0.85	1.02
SAKARYA	3.07	2.4	2.73	2.86	1.93	2.32	2.77	3.27	2.92	3.04	2.1	3.47
BOZCAADA	2.3	2.06	2.23	1.88	2.24	2.61	2.9	2.12	2.38	1.97	1.32	1.97
ADANA	3.34	3.62	2.59	1.89	1.84	1.94	2.06	1.71	1.98	2.46	2.85	3.31
SAMANDAG	1.71	1.83	2.13	1.73	1.87	2.17	2.59	2.08	2.01	1.87	1.87	2.06
ISKENDERUN	1.66	1.68	1.67	1.79	2.43	2.46	2.39	2.12	1.96	1.61	1.26	1.44
FETHIYE	3.25	3.15	2.78	2.3	2.15	2.49	2.99	2.19	2.03	3	2.74	3.45
MUGLA	1.57	1.94	2.03	1.65	1.66	1.93	1.79	1.75	1.72	1.42	1.13	1.3
AYDIN	1.6	1.91	1.78	1.69	1.65	1.84	2.08	1.84	1.76	1.62	1.42	1.64
BODRUM	2.86	3.13	2.77	2.48	2.28	2.77	3.17	2.68	2.76	2.31	2.01	2.57
ICEL	2.91	2.25	1.9	1.82	2.16	2.97	2.94	1.95	2.25	1.67	1.38	2.26
MARMARIS	6.42	5.3	4.53	3.78	4.22	4.55	5.47	4.3	4.57	3.6	4.32	5.18
KUSADASI	6.52	7.08	5.16	5.36	4.48	4.38	5.56	7.52	6.39	5.14	4.85	7.14

Data Envelopment Analysis is a linear programming based technique which aims to measure the relative performance of decision units in times when it is hard to make a comparison between inputs and outputs which use a number of different measures or which have different measurement units. “Decision Units” are management or economic organizations whose performances will be compared. The method was developed firstly by Charnes, Cooper and Rhodes in order to measure and compare technical efficiency. While an ordinary statistical method evaluates the producers according to an average producer using the measures of central tendency approach, DEA technique compares the each producer only with the best producers.

The most important goal of this method is to identify the inactivity rate and the sources in each decision making unit. By means of this characteristic, the method may provide direction to managers regarding decreasing the input rate or/and increasing the output rate. The most important innovation that the method offers is to measure without predicting any predetermined analytical production function in the environments where high output is obtained by using high input. Besides, the inputs and outputs are free from the measurement unit which is why it is possible to measure different dimensions at the same time.

In this article in addition to the model that is used comprehensively in literature and is in a way to the maximum benefit and the minimum cost in order to reach the goal of optimization in locating, an input-output model has been defined.

There are three basic methods used in data envelopment analysis, these are;

-CCR (Charnes-Cooper-Rhodes) Method

-BBC (Banker-Charnes-Cooper) Method

-Additive Method

In order to reach the efficient solution, DEA can use an input oriented (holding outputs constant and minimizing amount of inputs) or an output oriented approach (holding inputs constant and maximizing amount of outputs). Our DEA model provide information about how well location perform their tasks when compared to their references. Determination can be done assuming Constant Returns to Scale (CRS) which implies that increase in inputs leads to a proportional increase of outputs, or Variable Returns to Scale (VRS) which implies that increase in inputs leads to changes in outputs in a variable rate.

In this study we have used CCR and output-oriented models. By use of the output oriented of the CCR model of DEA, by minimizing inputs, the cities which can have the maximum output will be efficient and by respecting it the optimal location of turbines in the most efficient cities will be determined in this article.

CCR method is based on the assumption "constant returns to scale". If the activity of j. decision making unit is h_j, the goal should be the maximization of this value. So, the goal function can be stated as in the (Eq.2) formulation under the input oriented assumption.

$$\max h_j = \frac{\sum_{r=1}^{n} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \tag{1}$$

Constraints can be stated as in the (Eq.3) formulation.

$$\frac{\sum_{r=1}^{n} u_r y_r}{\sum_{i=1}^{m} v_i x_i} \leq 1$$
$$u_r \geq 0$$
$$v_i \geq 0 \tag{2}$$

As mentioned above, the solution of the fractional programming set is more difficult compared to the linear programming set. When the (Eq.1) and (Eq.2) formulations are stated with linear programming logic, (Eq.3) and (Eq.4) formulations can be achieved.

$$\max h_j = \sum_{r=1}^{n} u_r y_r \tag{3}$$

$$\sum_{i=1}^{m} v_i x_i = 1 \tag{4}$$

$$\sum_{r=1}^{n} u_r y_r - \sum_{i=1}^{m} v_i x_i \geq 0$$

$$u_r, v_i \geq 0$$

(Eq.3) and (Eq.4) formulations are organized for the input-oriented situation. If the output-oriented situation will be used for CCR method, the linear programming model will be as in the (Eq.5) and (Eq.6) formulations.

$$\min g_j = \sum_{i=1}^{m} v_i x_i$$

(5)

$$\sum_{r=1}^{n} u_r y_r = 1$$

$$-\sum_{r=1}^{n} u_r y_r + \sum_{i=1}^{m} v_i x_i \geq 0$$

$$u_r, v_i \geq 0$$

(6)

Considering whether the model is input-oriented or output-oriented, if a decision maker wants to make a decision regarding the activities of the decision points with CCR method, the above mentioned model must be applied for all decision points. When the model is solved for each decision point, total activity standards will be obtained for each decision point. If these standards are equal to 1', this indicates activity for decision points, if they are smaller than 1', this indicates inactivity for decision points.

2.2.2. Modified TOPSIS Method

Here we use the TOPSIS method, The TOPSIS method proposed by Hwang and Yoon in 1981 and is applied many of decision making problems [7]. In this paper, we represent a modified TOPSIS method which was proposed by Deng et al in 2000. The modified TOPSIS has been reported as a rational and comprehensible method. The concept of TOPSIS lets us compare objective weights.

The concept of TOPSIS is that the most preferred alternative should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution.

Let A = {A_1; A_2; … ; A_m} be a set of alternatives, W = {w_1; w_2; w_3; … ;w_n} be a set of weights and C ={C_1; C_2;…; C_n} be a set of criteria.

All the ratings are assigned to alternatives with respect to a decision matrix denoted by $X(x_{ij})_{mxn}$. Normally, a modified TOPSIS has a process like the following:

Step 1. Normalize the decision matrix.

The normalized value {r_{ij}} can be computed by:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}} \quad i=1,2,\ldots,m; \; j=1,2,\ldots,n \tag{7}$$

We will not need the above step if Efficiency scores are between 0 and 1 in DEA result.

Step 2. Determine positive and negative ideal solutions.

The positive ideal solution and negative ideal solution are determined, respectively as follows:

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} = \{(\max_j v_{ij} \mid j \in I_1), (\min_j v_{ij} \mid j \in I_2)\} \tag{8}$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{(\min_j v_{ij} \mid j \in I_1), (\max_j v_{ij} \mid j \in I_2)\} \tag{9}$$

I_1 represents benefit criteria, and I_2 represents cost criteria.

Step 3. Obtain the weighted separation measures for positive and negative ideal solutions.

Separation measures based on weighted Euclidean distance are calculated for positive and negative solutions, respectively.

$$D_i^* = \sqrt{\sum_{j=1}^{n} w_j (v_{ij} - v_i^*)^2} \qquad i=1,2,\ldots,n \qquad (10)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} w_j (v_{ij} - v_i^-)^2} \qquad i=1,2,\ldots,n \qquad (11)$$

w_j is the weight of the j^{th} criterion and $\sum_{j=1}^{n} w_j = 1$

Step 4. Calculate the relative closeness to the ideal solution and rank the alternatives.

The relative closeness for alternative A_i according to A^* is defined as follows:

$$C_i^* = \frac{D_i^-}{D_i^* + D_i^-} \qquad (12)$$

According to the relative closeness to the ideal alternatives, the bigger is the C*i, the better is the alternative Ai.

3. RESULTS AND ANALYSIS

By analyzing the results, critical indicators for each DMUs were identified. Land cost was the most critical indicator for about 85% of the cases and distance to power distribution networks was the most critical in15% of the cases. This shows the importance of land cost factors for selecting the location of solar plants within a city in Turkey. The results have been presented in Table 6. According to result obtained for year 2010, Bodrum, Marmaris, Sinop and Kusadasi are the most effective cities in the order shown, meaning that they are the most suitable cities for location of wind plants in Turkey for February.

As it can be seen in the following table, each city can find out that how much they must they change their inputs to be efficient.

Considering the Table 2 of average wind speeds and the comparison of that with efficiency values it becomes clear that although Istanbul, Gokceada, Balikesir and Izmir cities have greater values in wind speed, they're not accepted as efficient cities; considering it is evident that land price and also the distance from electricity distribution center has caused these cities to not be in the list of efficient cities.

The required resemblance percentage for locations (cities) to resemble a referenced location is given for each location in the references column in Table 3. Moreover, the redundancies in inputs and outputs are given in this table.

For instance, the city of Kusadasi is efficient in the second month but in order to be efficient in the first month it must change its input parameters, land prices and the distance with electricity distribution center. For Kusadasi, in the first month, if the land price decreases from 20 to 19.95 Turkish Lira (1TL ≈ 1.8$) and the distance from electricity distribution center decreases from 15 Km to 13.3 Km, this city will be efficient for February. In another example, in fifth month for Bodrum city, efficiency score is 0.81 and its benchmarks is Sinop with 0.83. This means that Bodrum could be efficient if reaches 0.83 entrances of the Sinop inputs for February.

As illustrated on the Table 2, monthly average wind speed at coast al towns in Aegean Sea and Black Sea are very high, as seen in Table 4, few of these cities (Sinop, Bodrum, Kuşadası, Gökçeada and Marmaris) are efficient. Because of the reason the prices of land cost in the Aegean Sea and Black Sea cities are very high in contrast to the efficient cities, and also another reason is being far from the electricity transmission networks.

The statistics and results of efficiency scores are given in Table 4.The cities which the efficiency score of them is 1 or nearly 1 are known as efficient cities.

Between these cities, the cities have been selected for establishment of wind turbines that in term of proximity to transformers and land cost can have the maximum outputs (average wind speed) with minimum inputs. For this reason, these are the best cities for establishment of the wind turbines.

Because the efficiency scores are changing 12 months we need to classify by TOPSIS method. The TOPSIS method assesses gives one answer for the efficiency scores which have been calculated for 12 months separately and by classifying according to the obtained results the highest numbers will show the most appropriate cities for establishment of wind turbines.

Table 3. Efficiency scores for February

DMU	Numbers on the right indicate the references for efficient DMUs (in cases with dark background colors); and the peer names and weight values for inefficient DMUs which are indicated by a white background		
	February	June	September
ZONGULDAK	BODRUM (1,00)	BODRUM (1.00)	BODRUM (1.00)
SINOP	8	BODRUM (0.10) ICEL (0.91)	BODRUM (0.27) MARMARIS (0.47)
SAMSUN	SINOP(2,00) BODRUM (1,00)	BODRUM (1.21) ICEL (1.83)	BODRUM (1.53) MARMARIS (0.93)
ORDU	KUSADASI (1,75)	MARMARIS (2.MARMARIS)	KUSADASI (1.75)
GIRESUN	KUSADASI (2,00)	MARMARIS (2.67)	KUSADASI (2.00)
TRABZON	KUSADASI (2,00)	MARMARIS (2.67)	KUSADASI (2.00)
ARTVIN	KUSADASI (1,25)	MARMARIS (1.67)	KUSADASI (1.25)
ISTANBUL	SINOP(11,09) BODRUM (2,43)	BODRUM (2.48) ICEL (0.43)	BODRUM (2.56) MARMARIS (0.22)
EDIRNE	KUSADASI (1,40)	MARMARIS (1.87)	KUSADASI (1.40)
GOKCEADA	KUSADASI (0,75)	MARMARIS (1.00)	KUSADASI (0.75)
BALIKESIR	SINOP(1,09)MARMARIS (1,00)	ICEL (2.00) MARMARIS (0.60)	BODRUM (0.36) MARMARIS (1.62)
IZMIR	SINOP(0.67)BODRUM(0,09)	BODRUM (0.20) ICEL (1.00)	BODRUM (0.38) MARMARIS (0.51)
MANISA	KUSADASI (1,50)	MARMARIS (2.00)	KUSADASI (1.50)
AFYON	KUSADASI (1,90)	MARMARIS (2.53)	KUSADASI (1.90)
USAK	KUSADASI (1,75)	MARMARIS (2.MARMARIS)	KUSADASI (1.75)
AKSARAY	KUSADASI (2.25)	MARMARIS (3.00)	KUSADASI (2.25)
DENIZLI	SINOP(1,58) MARMARIS (0,75)	ICEL (2.37) MARMARIS (0.28)	BODRUM (0.42) MARMARIS (1.49)
BURDUR	KUSADASI (3,25)	MARMARIS (4.MARMARIS)	KUSADASI (3.25)
ISPARTA	KUSADASI (2,00)	MARMARIS (2.67)	KUSADASI (2.00)
DIYARBAKIR	SINOP(2,08) MARMARIS (0,05)	BODRUM (0.20) ICEL (2.00)	BODRUM (0.56) MARMARIS (1.02)
HAKKARI	KUSADASI (0,75)	MARMARIS (1.00)	KUSADASI (0.75)
CANKIRI	KUSADASI (1,75)	MARMARIS (2.MARMARIS)	KUSADASI (1.75)
SAKARYA	KUSADASI (1,25)	MARMARIS (1.67)	KUSADASI (1.25)
BOZCAADA	KUSADASI (1,00)	MARMARIS (1.MARMARIS)	KUSADASI (1.00)
ADANA	SINOP(0.33)BODRUM (1,20)	BODRUM (1.23) ICEL (0.30)	BODRUM (1.29) MARMARIS (0.16)
SAMANDAG	MARMARIS (2,20) KUSADASI (0,60)	MARMARIS (3.00)	MARMARIS (2.20) KUSADASI (0.60)
ISKENDERUN	KUSADASI (2,50)	MARMARIS (3.MARMARIS)	KUSADASI (2.50)
FETHIYE	KUSADASI (0,75)	MARMARIS (1.00)	KUSADASI (0.75)
MUGLA	MARMARIS (2,40) KUSADASI (0,20)	MARMARIS (2.67)	MARMARIS (2.40) KUSADASI (0.20)
AYDIN	MARMARIS (2,00) KUSADASI (0,40)	MARMARIS (2.53)	MARMARIS (2.00) KUSADASI (0.40)
BODRUM	5	7	10
ICEL	SINOP(0,67) MARMARIS (0,20)	8	BODRUM (0.18) MARMARIS (0.51)
MARMARIS	7	24	12
KUSADASI	21	MARMARIS (1.02)	21

In Table 5, the values which these cities must reach in order to be efficient is shown.

Table 4. The results of DEA over 12 Month period (Efficiency Scores)

Months→ DMUs	1	2	3	4	5	6	7	8	9	10	11	12	*Std Dev	Max	Min
ZONGULDAK	0.73	0.95	0.87	0.83	0.54	0.53	0.44	0.54	0.59	0.69	0.87	0.74	0.16	0.95	0.44
SINOP	0.62	1.00	1.00	1.00	1.00	0.97	0.77	0.91	0.87	1.00	0.84	1.00	0.12	1.00	0.62
SAMSUN	0.20	0.16	0.12	0.14	0.14	0.16	0.14	0.18	0.15	0.10	0.19	0.20	0.03	0.20	0.10
ORDU	0.08	0.11	0.14	0.15	0.15	0.15	0.13	0.13	0.14	0.11	0.09	0.08	0.03	0.15	0.08
GIRESUN	0.08	0.14	0.13	0.15	0.13	0.14	0.10	0.09	0.11	0.14	0.05	0.09	0.03	0.15	0.05
TRABZON	0.13	0.16	0.17	0.13	0.16	0.13	0.12	0.13	0.17	0.17	0.14	0.12	0.02	0.17	0.12
ARTVIN	0.15	0.20	0.25	0.29	0.25	0.29	0.31	0.28	0.30	0.22	0.19	0.19	0.05	0.31	0.15
ISTANBUL	0.78	0.79	0.88	0.92	0.65	0.65	0.64	0.80	0.94	1.00	1.00	1.00	0.14	1.00	0.64
EDIRNE	0.26	0.22	0.24	0.25	0.27	0.21	0.19	0.19	0.21	0.22	0.21	0.19	0.03	0.27	0.19
GOKCEADA	0.97	0.98	1.00	1.00	0.79	0.70	0.64	0.71	0.88	1.00	1.00	1.00	0.14	1.00	0.64
BALIKESIR	0.27	0.39	0.30	0.50	0.41	0.37	0.43	0.69	0.57	0.50	0.30	0.39	0.12	0.69	0.27
IZMIR	0.77	0.77	0.81	0.70	0.64	0.79	0.70	0.71	0.75	0.72	0.78	0.78	0.05	0.81	0.64
MANISA	0.13	0.15	0.16	0.20	0.16	0.16	0.19	0.17	0.16	0.16	0.11	0.10	0.03	0.20	0.10
AFYON	0.14	0.23	0.24	0.27	0.23	0.24	0.22	0.22	0.20	0.22	0.14	0.15	0.04	0.27	0.14
USAK	0.12	0.15	0.16	0.17	0.17	0.18	0.14	0.14	0.14	0.14	0.11	0.09	0.03	0.18	0.09
AKSARAY	0.15	0.21	0.21	0.23	0.17	0.17	0.15	0.15	0.16	0.16	0.16	0.13	0.03	0.23	0.13
DENIZLI	0.22	0.33	0.26	0.27	0.22	0.22	0.20	0.21	0.24	0.32	0.31	0.33	0.05	0.33	0.20
BURDUR	0.08	0.14	0.13	0.12	0.11	0.10	0.08	0.07	0.09	0.10	0.09	0.08	0.02	0.14	0.07
ISPARTA	0.08	0.12	0.11	0.11	0.11	0.12	0.10	0.08	0.10	0.11	0.08	0.08	0.02	0.12	0.08
DIYARBAKIR	0.30	0.21	0.27	0.31	0.30	0.38	0.30	0.32	0.24	0.30	0.24	0.22	0.05	0.38	0.21
HAKKARI	0.23	0.28	0.45	0.40	0.44	0.44	0.37	0.33	0.37	0.42	0.19	0.13	0.11	0.45	0.13
CANKIRI	0.09	0.12	0.14	0.15	0.14	0.14	0.11	0.10	0.11	0.13	0.07	0.07	0.03	0.15	0.07
SAKARYA	0.29	0.27	0.35	0.43	0.27	0.31	0.30	0.35	0.37	0.42	0.24	0.34	0.06	0.43	0.24
BOZCAADA	0.27	0.29	0.36	0.35	0.40	0.43	0.40	0.28	0.37	0.34	0.19	0.24	0.07	0.43	0.19
ADANA	0.61	0.73	0.57	0.46	0.41	0.45	0.42	0.40	0.46	0.64	0.73	0.71	0.13	0.73	0.40
SAMANDAG	0.09	0.12	0.16	0.15	0.15	0.16	0.16	0.13	0.14	0.16	0.14	0.13	0.02	0.16	0.09
ISKENDERUN	0.08	0.09	0.11	0.13	0.17	0.16	0.13	0.11	0.12	0.11	0.07	0.07	0.03	0.17	0.07
FETHIYE	0.51	0.59	0.60	0.57	0.51	0.55	0.55	0.39	0.42	0.70	0.52	0.56	0.08	0.70	0.39
MUGLA	0.09	0.14	0.17	0.16	0.15	0.16	0.12	0.13	0.14	0.14	0.09	0.09	0.03	0.17	0.09
AYDIN	0.10	0.14	0.15	0.17	0.15	0.16	0.15	0.14	0.15	0.16	0.12	0.12	0.02	0.17	0.10
BODRUM	1.00	1.00	0.98	0.97	0.81	1.00	1.00	1.00	1.00	0.96	0.81	0.87	0.07	1.00	0.81
ICEL	0.75	0.65	0.60	0.65	0.70	1.00	0.88	0.64	0.80	0.63	0.51	0.71	0.13	1.00	0.51
MARMARIS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.86	1.00	0.94	0.97	1.00	0.04	1.00	0.86
KUSADASI	0.76	1.00	0.84	1.00	0.80	0.72	0.76	1.00	1.00	0.93	0.73	0.93	0.12	1.00	0.72
*Std dev	**0.31**	**0.34**	**0.32**	**0.32**	**0.27**	**0.29**	**0.28**	**0.30**	**0.32**	**0.32**	**0.32**	**0.35**			

*Standard Deviation

Table 5. Analysis of Efficiencies

	1	2	3	4	5	6	7	8	9	10	11	12
GOKCEADA	15 10	15 11.25	* **	15 11.25	15 10	15 10	15 10	15 11.25	15 11.25	* **	* **	* **
IZMIR	11.4 1.9	16.5 6.6	17.55 7.02	17.55 7.02	6,03 7,37	13 6	7.65 5.1	6.6 4.94	7.65 5.1	16.2 6.48	5.55 4.44	7.2 4.8
MARMARIS	* **	* **	* **	11.4 8.55	8,82 0,78	* **	* **	12.8 9.6	* **	10.05 8.04	11.7 9.36	* **
KUSADASI	19.95 13.3	* **	12.45 9.96	* **	11.7 14,03	11.7 14,03	11.7 14,03	* **	* **	17.55 14.04	19.35 15.48	12.45 9.96

*Land Cost
**Distance from Distribution

With constant input values, the efficiency value changes by increase of the monthly average wind and will be follow its changes (Figures 2-5). The Figure 2.5 shows that the efficiency scores and wind speed are parallel. These graphics of the cities which are efficient or are nearly efficient, indicate that they are efficient continuously in some months and have missed their efficiency in some other months numerically.

As the efficiencies which are 1 or nearly 1 are parallel to wind speed have high potential in selection of the optimal locations. It must be reminded that for the cities like Izmir (Fig.3) which their efficiency are nearly 1 for all months we can earn efficiency by reduction of land cost or distance to transformers.

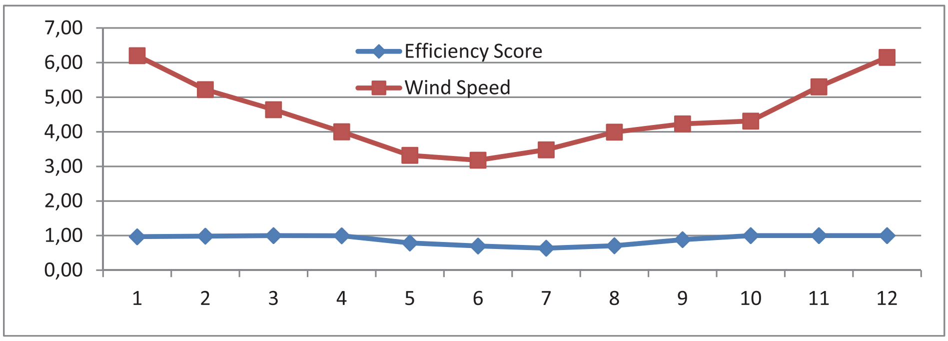

Figure 2. Comparison of Efficiency Scores by Average Wind over a 12 Month Period for Gokceada City

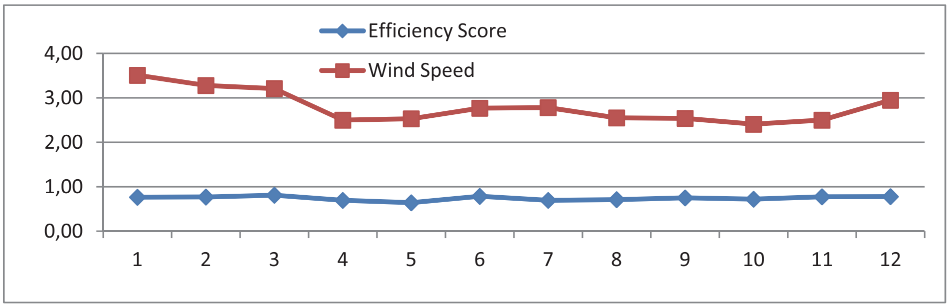

Figure 3. Comparison of Efficiency Scores by Average Wind over a 12 Month Period for Izmir City

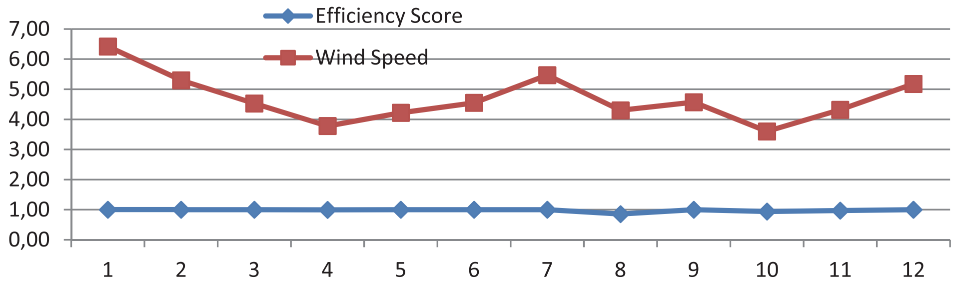

Figure 4. Comparison of Efficiency Scores by Average Wind over a 12 Month Period for Marmaris City

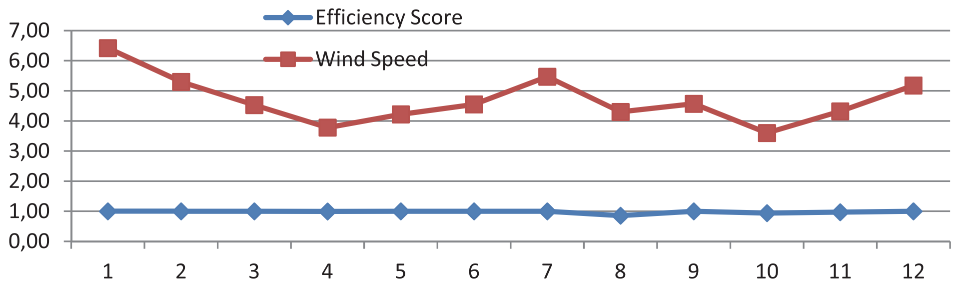

Figure 5. Comparison of Efficiency Scores by Average Wind over a 12 Month Period for Kusadasi City

The TOPSIS in this analysis; the efficiency analysis, has been calculated separately for each month and by use of these efficiency results and using the prioritizing method has been recognized and the distances have been specified from ideal answer and the priority of TOPSIS has been measured for 12 months and has been and has been specified with location(Table 6). The results obtained with currently established turbines in places where wind turbines are much fit 2,000 MW.

In terms of efficiency scores for the power production continuous in centrals, the assessment of centrals for 12 months would be a correct approach. For this reason even if the results of TOPSIS method be the same with average values of 12 months, it can make the analysis more valuable and give new dimension to the analysis.

4. CONCLUSION

Wind plants are very desirable as an alternative source of energy. Hence, determination of the optimum locations for use of this resource is a vital issue. Generally, average wind speed as a primary criterion is used for determining the optimum locations for wind plants. Therefore, in this approach some local and social considerations are ignored.

Some criteria such as distance to power distribution networks, land cost and monthly average wind speed are considered in this work. In this article, a DEA approach that uses a number of predefined indicators has been used to identity optimum locations of wind plants in Turkey, DEA was used to rank various locations' capabilities with respect to some output and input indicators for 34 cities in Turkey.

Table 6. TOPSIS score and average efficiency score for 12 months

DMUs	TOPSIS score	Average Efficiency Score for 12 months
MARMARIS	0,956	0,981
BODRUM	0,916	0,950
SINOP	0,865	0,915
KUSADASI	0,839	0,873
GOKCEADA	0,838	0,889
ISTANBUL	0,801	0,838
IZMIR	0,741	0,743
ICEL	0,695	0,710
ZONGULDAK	0,673	0,693
ADANA	0,546	0,549
FETHIYE	0,538	0,539
BALIKESIR	0,431	0,427
HAKKARI	0,345	0,338
SAKARYA	0,331	0,328
BOZCAADA	0,330	0,327
DIYARBAKIR	0,285	0,283
DENIZLI	0,264	0,261
ARTVIN	0,247	0,243
EDIRNE	0,223	0,222
AFYON	0,211	0,208
AKSARAY	0,173	0,171
SAMSUN	0,159	0,157
MANISA	0,156	0,154
TRABZON	0,145	0,144
USAK	0,144	0,143
AYDIN	0,144	0,143
SAMANDAG	0,142	0,141
MUGLA	0,134	0,132
ORDU	0,124	0,122
CANKIRI	0,117	0,114
ISKENDERUN	0,116	0,113
GIRESUN	0,116	0,113
BURDUR	0,101	0,099
ISPARTA	0,101	0,100

The obtained results for locating the most suitable lands for establishment of wind centrals in Turkey in the cases which are not computable as like as the vegetation, protected areas, the resident areas have not any conflict. Even though, the land cost which is determined in scientific researches has been used in analysis the costs are not considered by the selection of provinces and the capital of them but the optimum pricing for suitable land for the establishment of centrals and the distance to distribution networks has been recognized.

Before installation and implementation the wind powerhouses which are naturally compatible, according to the official accounting approaches, the report of the environment is getting ready.

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