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A Study on OSH Performance Measurement by PROMETHEE Method in Coal-Fired Thermal Power Plants

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Abstract: Occupational accidents in the world and in our country affect the energy sector as a serious problem. It has become important to take the necessary precautions for the uninterrupted continuation of energy. The effective prevention of occupational accidents and diseases by coal-fired power plants depends on their evaluation of OHS performance and continuing their improvement efforts. In the implementation phase of the OHS performance model in coal-fired thermal power plants, a total of 170 OHS performance measurement criteria, including 8 main criteria and 162 sub-criteria, were determined and 162 sub-criteria were evaluated with the PROMETHEE method. As a first step, the sub-criteria of the three riskiest sections in terms of OHS in coal-fired thermal power plants, which were previously selected with AHP, were evaluated by 10 occupational safety experts in the range of 0-100 for each coal-fired power plant alternative. Performance factor results were obtained by using the "Visual PROMETHEE" package program to obtain PROMETHEE results with criterion weights. The data obtained from alternative power plants were evaluated and prioritized with the PROMETHEE method based on the weights determined with the help of AHP according to the OHS performance measurement model we proposed, and coal-fired power plants were ranked. This study; An objective OHS performance measurement method based on measurable indicators, reflecting OHS performance in the most accurate way, practical to use, has been developed and applied in coal-fired thermal power plants.

Kömürlü Termik Santrallerde PROMETHEE Yöntemi ile İSG Performans Ölçümü Üzerine Bir Çalışma

Anahtar Kelimeler
Enerji,
İSG performansı,
Kömürlü termik santraller,
Promethee yöntemi

Öz: Dünyada ve ülkemizde iş kazaları ciddi bir sorun olarak enerji sektörünü etkilemektedir. Enerjinin kesintisiz devam etmesi için gerekli önlemlerin alınması önem kazanmıştır. Kömürlü termik santrallerin iş kazası ve meslek hastalıklarını etkili bir şekilde önlemesi, İSG performanslarını değerlendirmeleri ve iyileştirme çalışmalarını sürdürmelerine bağlıdır. Kömürlü termik santrallerde İSG performans modelin uygulama aşamasında, temelde 8 ana kriter ve 162 alt kriter olmak üzere toplamda 170 İSG performans ölçüm kriteri belirlenmiş ve PROMETHEE yöntemi ile 162 alt kriter değerlendirilmiştir. İlk iş olarak, kömürlü termik santrallerde İSG açısından daha önceden AHP ile seçilmiş olan en riskli üç bölümün alt kriterleri her kömürlü termik santral alternatifi için 0-100 aralığında 10 iş güvenliği uzmanı tarafından değerlendirilmiştir. Kriter ağırlıkları ile PROMETHEE sonuçlarını elde etmek için "Visual PROMETHEE" paket programı kullanılarak performans faktör sonuçlarına ulaşılmıştır. Alternatif santrallerden alınan veriler önerdiğimiz İSG performans ölçüm modeline göre AHP yardımıyla belirlenmiş ağırlıklara dayanarak PROMETHEE yöntemiyle değerlendirilip ve önceliklendirilmiş ve kömürlü termik santraller sıralanmıştır. Bu çalışma; ölçülebilir göstergelere dayalı, objektif, İSG performansını en doğru şekilde yansıtan, kullanımı pratik bir İSG performans ölçümü yöntemi geliştirilmiş ve kömürlü termik santrallerde uygulaması yapılmıştır.

1. INTRODUCTION

It is seen that the primary growth sector to meet the future electricity demand will be coal-fired power plants. Even if the use of renewable energy sources in energy production is increased, it is imperative to have coal-fired power plants to ensure continuity and reliability. It is necessary to analyze the situation of existing coal-fired power plants, to reveal the deficiencies in the field of OHS and to develop solutions that can be applied.

Today's intense competition environment requires businesses to manage their business processes more effectively. The golden rule for managing processes is to determine performance criteria and manage performance effectively. At this point, first performance needs to be defined and the method of performance measurement needs to be determined. Since performance measurement is directly related to the company's outputs, it is important both in terms of comparing the company's performance with previous periods and making comparisons with its competitors [1].

For the development of the system, it is important to measure and analyze it. It is necessary to analyze the current situation of the businesses and observe where the changes made take the businesses. Measuring the impact of improvement studies in the field of OHS on OHS performance is an important problem. The OHS performances of coal-fired power plants were generally based on a limited number of information, such as the number of occupational accidents that occurred in previous years, and the observations made by an expert in a limited time at the plant. The information obtained using a limited number of indicators does not reflect actual performance. There is no sector-specific objective, commonly-accepted, simple measurement system that measures the OHS performance of multiple coal-fired power plants. Many criteria are evaluated when examining the occupational health and safety performance of coal-fired thermal power plants. These criteria are effective risk factors that can help to measure the occupational health and safety performance of thermal power plants in all parts of thermal power plants. All of the performance indicators that are used to measure the OHS performance of coal-fired thermal power plants are values that can be measured numerically and practically. In our study, the data to be obtained from thermal power plants are sufficient to measure the performance scores based on these developments. The occupational health and safety performances of the power plants were measured practically, quickly and objectively using the PROMETHEE method with the numerical data obtained from the occupational safety experts working in X, Y and Z thermal power plants [2].

In the Analytical Hierarchy Process (AHP) method was developed by Thomas L. Saaty and alternatives are listed and then compared pairwise according to their contribution to reaching each objective or criterion.This method (AHP) an important indicator which is the number of criteria and it affects result consistency because more than seven criteria lead to an increase in inconsistency.In application of this AHP method to calculate weight it is important to use experts to evaluate criteria because this affects the alternative's values in the future when MCDA methods are using criteria weight. When weights are calculated using the AHP method, these values can be used in every MCDA method. Also, after the AHP method, results can make conclusions about the indicated values and which indicator can solve the problem [3].

A distinctive feature of the Promethee method compared to other methods is that different function types can be selected while comparing alternatives for different evaluation criteria. Although this method is a simple sorting method that can be easily applied, it is the disadvantage of being subjective [4].

PROMETHEE is the most attractive outranking method because of its mathematical simplicity and transparency.PROMETHEE where a large number of alternatives arise reaches its computational limits quickly [5].

The PROMETHEE method has two main stages, which are PROMETHEE I and PROMETHEE II. The main difference that distinguishes the PROMETHEE method is that it takes into account the importance weights of each evaluation criterion and can apply different function types for each evaluation criterion [6].

The PROMETHEE and PROMETHEE II methods found applications in disciplines such as urban planning and architecture, land management, logistics, healthcare, banking, energy and quality analysis in general.

In their paper, Zorkirişçi and Rençber measured the financial performances of 20 public, private or foreign capital banks operating in Turkey using BWM-based TOPSIS, PROMETHEE and COPRAS methods and interpreted the findings comparatively. However, they concluded that the PROMETHEE method is more applicable in terms of ease of application and useful information it provides[7]. In their paper, Bağcı and Esmer the ranking of 8 public factoring companies was conducted by using Promethee Method which are registered in the Public Disclosure Platform [8].

In their paper, Atıcı and Ulucan in the first application, various hydroelectric plant projects are ranked using ELECTRE method. The second application ranks multiple wind plant projects using PROMETHEE technique [9].

In their paper, Vivas et al., who compared reports on sustainable development. Using the PROMETHEE method [10].

In the implementation phase of the proposed model, a total of 170 OHS performance measurement criteria, including 8 main criteria and 162 sub-criteria, were determined and 162 sub-criteria were evaluated with the PROMETHEE method. As a first step, the sub-criteria of the three riskiest sections in terms of OHS in coal-fired thermal power plants, which were previously selected with AHP, were evaluated by 10 occupational safety experts in the range of 0-100 for each coal-fired power plant alternative. The points given for the determined criteria were entered into the program. In the next step, normalization was applied to the importance weights obtained by the AHP method. After normalizing the importance weights, the program was introduced. In the normalization process, first of all, the lowest criteria of each branch in each main criterion were determined and the totals of all these criteria were taken.

In the second step, each lowest criterion was divided into this sum and normalized weights were obtained. In the last step, each of the obtained criterion weights was multiplied by its main criterion weight and the weights entered into the program were obtained. Afterwards, the preference function was selected according to the criteria. The V type function was chosen as the preference function. The reason for this is; This type of function is suitable for quantitative data and the criteria are especially intended to be used with values above a certain average, while even small deviations below this value are taken into account.

A high positive advantage indicates that one alternative option is a better choice or performs better than others. If the negative superiority value is high; indicates that that option is a worse choice than the others, or that its performance is poorer.

The PROMETHEE method differs from other multi-criteria decision-making methods in that it gives a ranking among the alternatives and calculates according to the ideal solution [11,12,13].

The method evaluates coal-fired power plants, which are the basis of the decision-making problem, based on the determined criterion weights and prioritizes the alternatives partially and fully with pairwise comparisons. A screenshot of the program is shown in Figure 1.

PK9	PK10	PF1	PF2	PF3	PF4	PF5	PF6	PS1	PS2	PS3	PS4	PS5	PS6
unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit	unit
max	max	max	max	max	max	max	max	max	max	max	max	max	max
0,10	0,09	0,16	0,13	0,17	0,11	0,19	0,24	0,21	0,13	0,25	0,13	0,13	0,06
V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape
absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
70,00	100,00	60,00	40,00	50,00	10,00	0,00	50,00	20,00	20,00	100,00	20,00	80,00	20,00
100,00	100,00	90,00	100,00	90,00	100,00	70,00	100,00	90,00	100,00	100,00	100,00	100,00	100,00
83,33	100,00	80,00	76,67	76,67	50,00	30,00	73,33	50,00	63,33	100,00	50,00	93,33	66,67
12,47	0,00	14,14	26,25	18,86	37,42	29,44	20,55	29,44	33,00	0,00	35,59	9,43	33,99
100,00	100,00	90,00	100,00	90,00	100,00	0,00	100,00	90,00	100,00	100,00	100,00	100,00	100,00
80,00	100,00	60,00	40,00	50,00	10,00	20,00	50,00	20,00	70,00	100,00	20,00	80,00	80,00
70,00	100,00	90,00	90,00	90,00	40,00	70,00	70,00	40,00	20,00	100,00	30,00	100,00	20,00

Figure 1: The "Visual PROMETHEE" startup solution screen

Performance factor results were obtained by using the "Visual PROMETHEE" package program to obtain PROMETHEE results with criterion weights. With this software, PROMETHEE I and alternatives were compared on the basis of determined criteria, partial priorities were obtained, and then interpreted with graphics.

As a result of the comparison of PROMETHEE II and alternatives on the basis of the determined criteria, clear priorities are shown in the tables. Performance score results are explained below; The data obtained from alternative power plants were evaluated and prioritized with the PROMETHEE method based on the weights determined with the help of AHP according to the OHS performance measurement model we proposed, and coal-fired power plants were ranked.

Initial matrices are given and results are shown in the program used for PROMETHEE calculation separately for the coal parking area, ash slag disposal plant and boiler maintenance service. Values for the ideal solution are indicated. The same processes were evaluated with the PROMETHEE method for a total of 162 sub-criteria by entering the data obtained from all power plants at once.

2. MATERIAL AND METHOD

2.1. Determination of OHS Performance Rankings of Coal-Fired Thermal Power Plants by PROMETHEE Method

2.1.1. Evaluation of coal parking yard OHS performance results by PROMETHEE method

63 units of 1,000 performance criteria were evaluated for the coal parking site. The results obtained are described in Figure 2 and Figure 3.

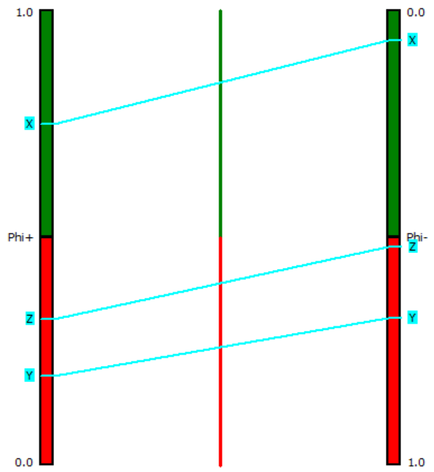

Figure 2: PROMETHEE I partial ranking of coal parking sites

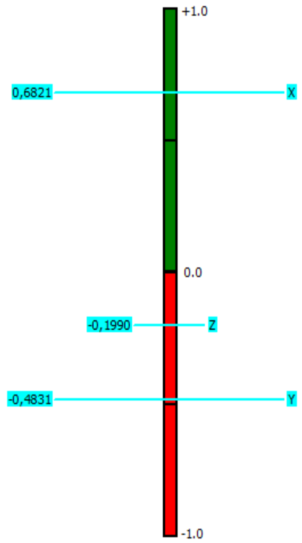

Figure 3: Full sequencing of coal parking sites with PROMETHEE II

According to PROMETHEE I; As a result of the calculations, as can be seen in Figure 2, X coal-fired power plant was the best alternative in terms of partial ranking of the coal parking area section. It is followed by the Z and Y coal-fired power plants. For clear benchmarking, PROMETHEE 2 analysis is required. As a result of the calculations made according to Promethee II, the full ranking result is given in Figure 3.

2.1.2. Evaluation of OHS performance results of ash slag disposal plant by PROMETHEE method

39 OHS performance criteria of the ash slag disposal plant were evaluated. The results obtained are described in Figure 4 and Figure 5.

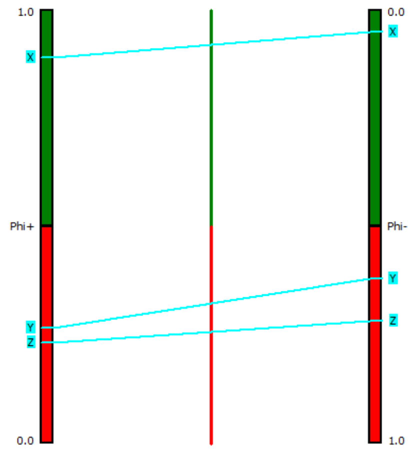

Figure 4: Partial sequencing of ash slag disposal plants with PROMETHEE I

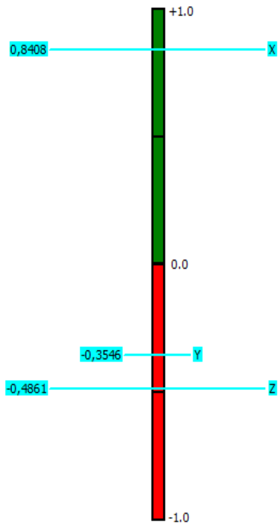

Figure 5: Full sequencing of ash slag disposal plants with PROMETHEE II

According to PROMETHEE I; As a result of the calculations, as can be seen in Figure 4, the X coal-fired thermal power plant was the best alternative in terms of partial ranking of the ash slag disposal plant section. It is followed by the Y and Z coal-fired thermal power plants. For net benchmarking, PROMETHEE II analysis is required. As a result of the calculations made according to Promethee II, the full ranking result is given in Figure 5.

2.1.3. Evaluation of OHS performance results of boiler maintenance service with PROMETHEE method

Boiler maintenance service 60 OHS performance criteria were evaluated. The results obtained are described in Figure 6 and Figure 7.

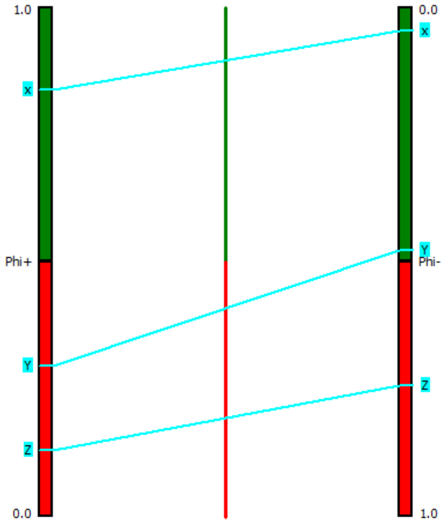

Figure 6. Partial ranking of boiler maintenance services with Promethee

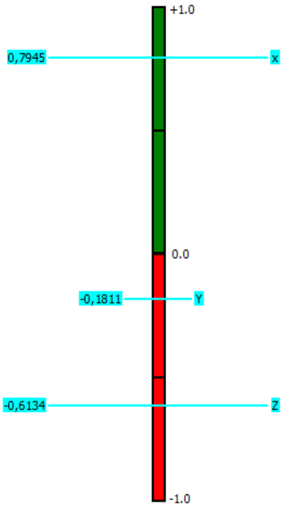

Figure 7. Full ranking of boiler maintenance services with Promethee II

According to PROMETHEE I; As a result of the calculations, as can be seen in Figure 6, the X coal-fired power plant was the best alternative in terms of partial ranking of the boiler maintenance service section. It is followed by the Y and Z coal-fired thermal power plants. For net benchmarking, PROMETHEE II analysis is required. As a result of the calculations made according to Promethee II, the full ranking result is given in Figure 7.

2.1.4. Evaluation of OHS performance results of coal-fired power plants handled by PROMETHEE method

A total of 162 performance criteria were evaluated for all coal-fired power plants. The results obtained were evaluated according to PROMETHEE I and II with the Visual PROMETHEE program, and the results obtained are explained in Figure 8 and Figure 9.

As a result of the calculations made with the data obtained from coal-fired thermal power plants, X coal-fired thermal power plant was the best alternative in terms of partial ranking of OHS performance in Figure 8. Then it became the Y and Z coal-fired power plants. For net benchmarking, PROMETHEE II analysis is required. As a result of the calculations made according to Promethee II, the full ranking result is given in Figure 9.

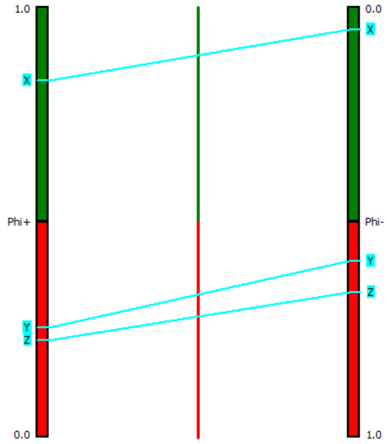

Figure 8. Partial ranking of coal-fired power plants with Promethee I

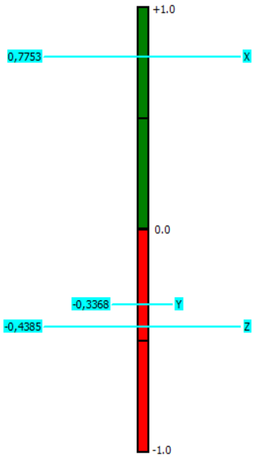

Figure 9. Full ranking of coal-fired power plants with Promethee II

3. RESULTS

In this study, an OHS performance model based on measurable indicators with multi-criteria decision-making methods, objective, fast, practical reflecting the occupational health and safety performance in coal-fired power plants in the most accurate way was developed and the OHS performance of 3 coal-fired thermal power plants was measured. Since the current situation is analyzed practically and quickly before accidents occur with the multi-criteria decision-making methods we have made for coal-fired thermal power plants and the OHS performance measurement model, it makes it possible to prevent occupational accidents by proactively taking preventive and corrective measures.

With the latest ranking observed in Table 1, OHS performance results can be seen more clearly.

Table 1. Coal parking area PROMETHEE II ideal solution values

Sıra	Kömürlü termik santraller	Phi	Phi+	Phi-
1	X	0.6821	0.7491	0.0670
2	Z	-0.1990	0.3204	0.5194
3	Y	-0.4831	0.1946	0.6777

According to the net ranking made in Table 1, it is the X coal-fired thermal power plant with the best OHS performance. Then, this ranking; Z coal-fired power plant was followed by Y coal-fired power plant.
With the latest ranking observed in Table 2, OHS performance results can be seen more clearly.

Table 2. PROMETHEE II ideal solution values of Ash slag disposal plant

Sıra	Kömürlü termik santraller	Phi	Phi+	Phi-
1	X	0.8281	0.8776	0.0495
2	Y	-0.3673	0.2539	0.6212
3	Z	-0.4608	0.2310	0.6918

According to the net ranking made in Table 2, it is the X coal-fired power plant with the best performance. According to our ranking study; Y coal-fired power plant was followed by Z coal-fired power plant.

With the latest ranking observed in Table 3, OHS performance results can be seen more clearly.

Table 3. Boiler maintenance service PROMETHEE II ideal solution values

Sıra	Kömürlü termik santraller	Phi	Phi+	Phi-
1	X	0.7945	0.8396	0.0451
2	Y	-0.1811	0.2964	0.4774
3	Z	-0.6134	0.1303	0.7437

According to the net ranking made in Table 3, it is the X coal-fired power plant with the best performance. Then, this ranking; Y coal-fired power plant was followed by Z coal-fired power plant.
By subtracting negative advantages from positive advantages, full sequencing was obtained with PROMETHEE II. With the latest ranking observed in Table 4, OHS performance results can be seen more clearly.

Table 4: PROMETHEE II ranking values of coal-fired thermal power plants

Sıra	Kömürlü termik santraller	Phi	Phi+	Phi-
1	X	0.7753	0.8286	0.0533
2	Y	-0.3368	0.2549	0.5917
3	Z	-0.4385	0.2253	0.6638

4. DISCUSSION AND CONCLUSION

According to the net ranking with Promethee II, it is the X coal-fired power plant with the best performance. Then, this ranking; Y coal-fired power plant was followed by Z coal-fired power plant.

This study provides superiority over other studies in terms of the fact that all of the performance indicators are quantitative, measurable, fast for performance measurement and require low expertise. This study is important in terms of giving an idea to researchers about measuring OHS performance, paving the way and applying it in the energy sector.

REFERENCES

[1] Bağcı, H., & Yüksel Yiğiter, Ş. (2019). BİST'te yer alan enerji şirketlerinin finansal performansının SD ve WASPAS yöntemleriyle ölçülmesi.

[2] Ersoy N. A study on occupational health and safety performance model in thermal power plants. Ph.D. Thesis, Üsküdar University, Istanbul, 2023.

[3] Zlaugotne, B., Zihare, L., Balode, L., Kalnbalkite, A., Khabdullin, A., & Blumberga, D. (2020). Multi-criteria decision analysis methods comparison. *Rigas Tehniskas Universitates Zinatniskie Raksti*, *24*(1), 454-471.

[4] Yılmaz, B., Dağdeviren, M. Comparative Analysis of PROMETHEE and Fuzzy PROMETHEE Methods in the Equipment Selection Problem, Gazi University Journal of Engineering and Architecture Faculty. 2010; 25(4), 811-826.

[5] Sotiropoulou, K. F., & Vavatsikos, A. P. (2021). Onshore wind farms GIS-Assisted suitability analysis using PROMETHEE II. *Energy Policy*, *158*, 112531.

[6] Şenkayas, H., Hekimoğlu, H. Application of PROMETHEE Method to the Multi-Criteria Supplier Selection Problem. Journal of Productivity. 2013; (2), 63-80.

[7] Zorkirişçi, E. D., & Rençber, Ö. F. BWM Tabanlı TOPSIS, PROMETHEE ve COPRAS Yöntemlerinin Karşılaştırılması: Bankaların Finansal Performansları Üzerine Bir Uygulama. *Süleyman Demirel Üniversitesi Vizyoner Dergisi*, *14*(39), 1030-1045.

[8] Bağcı, H., & Esmer, Y. (2016). PROMETHEE yöntemi ile faktoring şirketi seçimi. Beykent Üniversitesi Sosyal Bilimler Dergisi, 9(2).

[9] Atıcı, K. B., & Ulucan, A. (2009). Enerji Projelerinin Değerlendirilmesi Sürecinde Çok Kriterli Karar Verme Yaklaşımları ve Türkiye Uygulamaları. *Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *27*(1), 161-186.

[10] Vivas, R.; Sant'anna, Â.; Esquerre, K.; Freires, F. Çok kriterli model ile sürdürülebilirlik performansının ölçülmesi: Bir vaka çalışması. *Sürdürülebilirlik* 2019, *11*, 1–13.

[11] Brans, J.P., Vincke, P. A Preference Ranking Organization Method: The PROMETHEE Method for MCDM. Management Science, 1985; 31(6), 647-656.

[12] Brans, J.P., Vıncke, P., Mareschal, B. How to Select and How to Rank Projects: The PROMETHEE Method. European Journal of Operational Research, 1986;24, 228-238.

[13] Dağdeviren, M., Eraslan, E. Supplier Selection with PROMETHEE Ranking Method. Gazi University Journal of Engineering and Architecture, 2008; 23(1), 69-75.