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# Green Supplier Selection by Using COPRAS And EDAS Methods

## COPRAS ve EDAS Yöntemleriyle Yeşil Tedarikçi Seçimi

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## ABSTRACT

Sustainability as a concept; includes economic, social and environmental approaches in relation to each other and also supply chain components. In this context, the right suppliers were selected, which is the most important component for the integration of a sustainable supply chain process. The right suppliers that focus on green practices are important for sustainability. At this point, multi-criteria decision-making techniques, which provide the most important decision support opportunity, also provide rationality and convenience for decision makers in the selection of green suppliers. In this context, firstly a literature search was conducted in the study and the criteria used in the selection of green suppliers, which could be discussed in three sub-headings, were determined. At this stage; Resource Utilization and Green Competence (C1-Green Storage, C2-Green Recycling, C3-Green Production Capacity, C4-Green Packaging, C5-Resource Consumption, C6-Pollution Control), Economic Criteria (C7-Logistics Costs, C8-Product Costs, C9-Delivery Time) and Quality (C10-Error Rate, C11-Warranty and Rights Policies, C12-Environmental Competencies and Documents). Then, the determined criteria were weighted and finally, green suppliers were selected using COPRAS and EDAS, which are the multi-criteria decision-making techniques that have made significant improvements in recent years. As a result, the most suitable supplier was selected among the determined 7 alternative suppliers. Although there is a difference in the ranking made according to the selections by using both methods, the supplier A2 took the first places and came to the fore. The reason for choosing two different techniques in the study is that the techniques give similar results with each other and thus the strengths of the techniques are determined. In addition, it is to contribute to the correctness of a decision to be made at the strategic level at the first time, especially by preventing possible mistakes.

**Keywords:** Green Supplier, Logistics, Multi-Criteria Decision making, COPRAS, EDAS.

## ÖZ

Kavram olarak sürdürülebilirlik; birbirleriyle ilişkili ekonomik, sosyal ve çevresel yaklaşımların yanı sıra tedarik zinciri bileşenlerini içerir. Bu kapsamda sürdürülebilir bir tedarik zinciri süreci için en önemli bileşen olan doğru tedarikçi seçimi önemlidir. Yeşil uygulamalara odaklanan tedarikçiler, sürdürülebilirlik için ayrıca önemlidir. Bu noktada en önemli karar destek fırsatını sağlayan çok kriterli karar verme teknikleri de yeşil tedarikçi seçiminde karar vericilere rasyonellik ve kolaylık sağlamaktadır. Bu kapsamda çalışmada öncelikle literatür taraması yapılmış ve üç alt başlıkta ele alınabilecek yeşil tedarikçi seçiminde kullanılan kriterler belirlenmiştir. Bu aşamada; Kaynak Kullanımı ve Yeşil Yetkinlik (K1-Yeşil Depolama, K2-Yeşil Geri Dönüşüm, K3-Yeşil Üretim Kapasitesi, K4-Yeşil Paketleme, K5-Kaynak Tüketimi, K6-Kirlilik Kontrolü), Ekonomik Kriterler (K7-Lojistik Maliyetleri, K8-Ürün Maliyetleri, K9-Teslim Süresi) ve Kalite (K10-Hata Oranı, K11-Garanti ve Haklar Politikaları, K12-Çevresel Yeterlilikler ve Belgeler). Daha sonra belirlenen kriterler ağırlıklandırılmış ve nihayet son yıllarda önemli gelişmeler kaydeden çok kriterli karar verme teknikleri olan COPRAS ve EDAS yöntemleri kullanılarak 7 alternatif tedarikçi arasından en uygun yeşil tedarikçi seçimi yapılmıştır. Her iki yöntem kullanılarak yapılan seçimlere göre yapılan sıralamada farklılık olsa da tedarikçi A2 ilk sırayı alarak öne çıkmıştır. Böylece tekniklerin birbirlerini destekleme durumlarına göre güçlü yönleri belirlenmiştir. Ayrıca olası uygulama hatalarının önüne geçilerek, stratejik düzeyde alınacak bir kararın ilk seferde doğru olmasına katkı sağlanmıştır.

**Anahtar Kelimeler:** Yeşil Tedarikçi, Lojistik, Çok Kriterli Karar Verme, COPRAS, EDAS.

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## 1. INTRODUCTION

In recent years, the world has been trying to understand the concept of sustainability and what needs to be done to achieve this. The concept of sustainability, which has three dimensions: economic, social and environmental, is a very broad concept. Therefore, there is a need for a perspective that handles all these dimensions together. Sustainability, which requires providing prosperity to present generations without consuming the resources of future generations, is the main problem especially of production processes. Because production is dependent on a wide variety of resources. The efficient use of resources is as important as their correct supply. At this point, choosing the right supplier becomes important.

The supplier selection problem is a common problem of all businesses. Because establishing a sustainable relationship is one of the most important issues in the selection of suppliers. Sustainability is directly related to the green practices of suppliers. It is possible to establish and maintain a longer-term relationship with a supplier that attaches importance to green practices.

In this context, the problem of choosing a sustainable supplier was solved by using some green application-oriented criteria. Multi-criteria decision-making techniques, which are very useful in decision making problems due to many criteria at different weight levels, are a good assistant in complex decision problems. For this purpose, COPRAS and EDAS methods, which are the multi-criteria decision-making techniques that have become increasingly important in recent years, have been used.

First, 12 criteria that were evaluated to define a supplier best were determined and these criteria were weighted by taking expert opinion. Then, 7 alternative suppliers were listed using COPRAS and EDAS methods. There are two main reasons for choosing two methods. By comparing the results of the two methods, the status of the methods to support each other was revealed. In addition, by avoiding possible mistakes, it is possible to make the right decision at the first time.

## 2. CONCEPTUAL FRAMEWORK

There are many studies in the literature on supplier and green supplier selection. Most of these include the analysis made with multi-criteria decision-making techniques. The methods and criteria used in these studies are different. In the selection of criteria, it is considered that the work field is important. Because it is normal for different criteria to gain importance for suppliers to be determined for different work fields. However, in this study, the common ones among these criteria were preferred. In this section, some of the studies using different methods and different criteria are shared.

Kuo et.al. (2010) selected the green supplier by neural artificial network and data envelopment analysis. They used 5 main criteria and 24 sub-criteria as follows; quality (reject rate, management commitment to quality, process improvement, warranties and claim policies, quality assurance), cost (price performance value, compliance with sectoral price behaviour, transportation cost), delivery (order fulfil rate, lead time, order frequency), service (responsiveness, stock management, willingness, design capability), environment (eco-design requirements for energy using products, ozone depleting chemicals, restriction of hazardous sunstances, certified requirement of environmental management system, waste electrical and electronic equipment), corporate social responsibility (the interests and rights of employee, the rights of stakeholders, information disclosure, respect for the policy). At the end of the study they selected the best alternative in between 12 different alternative green suppliers.

Lee et.al. (2009) selected the green supplier by using fuzzy analytic hierarchy process. They used 6 main criteria and 23 sub-criteria as follows; quality (quality-related certificates, capability of quality management, capability of handling abnormal quality), technology capability (technology level, capability of R&D, capability of design, capability of preventing pollution), pollution control (air emissions, waste water, solid wastes, energy consumption, use of harmful material), environment management (environment-related certificates, continuous monitoring and regulatory compliance, internal control process, green process planning), green products (recycle, green packaging, cost of component disposal), green competencies (material used in the supply components that reduce the impact on natural resources, ability to alter process and product for reducing the impact of natural resources, social responsibility, ratio of green customers to total customers). Finally they selected the best alternative in between three different alternative green suppliers.

Aguezzoul et.al. (2006) selected the best 3PL providers based on three criteria; geographical coverage, quality control and services provided. In the study, geographic coverage means; the 3PLs providers must have warehouses in France, can serve the Maghreb and East of Asia and must have warehouses in North of France and Paris departments. Quality control means, Total Quality Management and logistics audit. Range of services offered means, international transit, intermodal transport, inventory control, just in time, cross-docking, co-packing, and reverse logistics. In the study where they used the ELECTRE method, each criterion was weighted as 5, 3 and 4, respectively. They decided on the most suitable 3PL provider among 14 alternatives.

Min (1993) selected the best foreign supplier by using one of the multi-criteria decision making techniques, MAUT method. He used 7 main criteria and 18 sub-criteria for his study as follows; financial terms (cost, freight terms, payment terms), quality assurance (quality control, quality team visits), perceived risks (political stability, foreign Exchange rate, legal claims, labour disputes, local price control), services performance (on-time delivery, technical assistance), buyer-supplier partnerships (financial stability, negotiability), cultural and communication barriers (cultural similarity, ethical standards, ADI capability), trade restrictions (tariffs and customs duties, counter-trade). In this study he selected the best supplier from the alternatives of Mexican, Taiwanese, Korean, Japanese and Canadian suppliers.

## 3. METHODOLOGY

Decision making is a process that starts with the existence of a problem. In order for a problem to be decided, there must be at least two alternative solutions for the solution of this problem. The majority of decisions to be made in environments of certainty, uncertainty and risk are complex (Demirci, 2020: 36-37). Because there are many criteria that affect the problem most of the time and the weights of these criteria are also different from each other. At this point, multi-criteria decision-making techniques, which have made significant progress in recent years and are frequently used in the literature, provide significant support to decision makers. Nowadays, there are numerous multi-criteria decision making techniques, which are widely used, are applied.

The use of multi-criteria decision making techniques will allow decision problems to be handled in small pieces and greatly facilitated, and will help decision-makers make more rational decisions (Demirci, 2018: 846).

Two different multi-criteria decision making techniques were used in this study. In this section, the theoretical background about COPRAS and EDAS methods used in green supplier selection is shared. Thus, it is aimed that if both methods support each other and to prevent possible mistakes during the application phase.

### 3.1. COPRAS Method

COPRAS (COmplex PRoportional ASsessment), which has an application similar to the Weighted Sum method, was proposed by Zavadskas et al in 1994. The Weighted Sum method takes into account only the utility criteria, and the cost criteria must be converted into utility criteria before normalization. This application requirement, which may pose a problem in other methods, was eliminated by the COPRAS method and made it superior (Kaklauskas vd., 2006: 460; Mousavi-Nasab ve Sotoudeh-Anvari, 2017: 241; Podvezko, 2011: 137-138).

The method involves a simpler process than some other Multi-Criteria Decision making Methods. COPRAS method is based on maximization of benefit criteria and minimization of cost criteria. Hence, the method can be applied to decision problems for maximization and minimization purposes. In the solution process, both groups of criteria are handled separately. Here, one of the issues that will occupy the decision maker the most is data with negative value and they need to be transformed (Arslan, 2018: 61). While many methods aim to rank the decision alternatives according to a certain superiority, the COPRAS method reveals how much better / worse one is than the other in percentage when comparing the alternatives. The COPRAS method, which is suitable for both quantitative and qualitative criteria, is based on the direct and proportional dependencies of the importance and priority of the alternatives. In the implementation phase, the importance of the alternatives compared with each other is determined depending on their positive or negative status according to their characteristics. The criterion values are used in maximizing the utility criteria and minimizing the cost side criteria.

Some important advantages of the method over other methods can be listed as follows (Özbek, 2017: 243-244);

- There is a much simpler application process compared to most of the multi-criteria decision making techniques.

- Allows the alternatives to be listed according to their performance.

- Can evaluate both quantitative and qualitative criteria.

- Whether minimization or maximization of criteria, it has the ability to calculate both ways.

- It generates information as a percentage not only about the good / bad status of the compared alternatives, but also about how good / bad they are.

- It has the ability to produce solutions with a simple Excel application without the need for a special program.

- No matter how high the number of alternatives is, the application time is short and easy, as it does not require binary comparison of the alternatives.

The implementation stages of the management can be specified as follows (Hashemkhani Zolfani ve Bahrami, 2014: 542-543; Özbek, 2017: 246-247);

*Determining the Decision Matrix;* At this stage, there is a mxn-dimensional decision consisting of m decision alternatives to be compared (i is to be 1 to m) and n number of decision criteria (j is to be 1 to n) to be based on this comparison. matrix is created. The decision matrix will be seen by Equation 1.

$$X = \begin{matrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix} \qquad 1.$$

*Standardization of Decision Matrix;* At this stage, first of all, the decision matrix should be normalized by using the equation 2. Accordingly, criterion weights should be determined by using some other multi-criteria decision making techniques or expert opinions. In this study, expert opinion was obtained for the criterion weights. At the equation 2. $q_j$ shows criterion weights.

$$d_{ij} = \frac{x_{ij} q_j}{\sum_{i=1}^{m} x_{ij}} \qquad 2.$$

*Sum of Weighted Normalized Indexes;* For the larger $S_{+i}$ value of the maximization criteria calculated with the help of Equation 3. And also, The smaller the $S_{-i}$ value of the minimization criteria calculated with the help of Equation 4.

$$S_{+i} = \sum_{j=1}^{n} d_{+ij} \qquad 3.$$

$$S_{-i} = \sum_{j=1}^{n} d_{-ij} \qquad 4.$$

*Calculating the Relative Importance of Alternatives;* Relative importance values ($Q_i$) of all alternatives compared with each other by using the Equation 5. According to this calculation, the largest $Q_i$ value in the ranking has the highest relative importance.

$$Q_i = S_{+i} + \frac{S_{-min.} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{=1}^{m} \frac{S_{-min.}}{S_{-i}}} \qquad 5.$$

*Determining the Benefit Level of Alternatives;* At this stage the benefit level of the alternatives $N_i$ is calculated by using the equation 6. All alternatives are ranked in descending order.

$$N_i = \left(\frac{Q_i}{Q_{maks.}}\right) * 100\% \qquad 6.$$

### 3.2. EDAS Method

The main basis of the EDAS (Evaluation Based on Distance from Average Solution) method proposed by Ghorabaee et al. (2015) is the two distance measurements defined as Average Positive Distance (PDA) and Mean Negative Distance (NDA). Accordingly, evaluation of alternatives in practice is made according to the average of these two values with the high PDA and low NDA values they obtain (Stanujkic vd., 2017: 7).

The application stages of the EDAS method are as follows (Keshavarz Ghorabaee vd., 2015: 438-441; Karabasevic, 2018: 58-59);

*Determining the alternatives and the criteria that best represent them;* At this stage, the alternatives to be evaluated and the criteria that will best explain these alternatives are determined.

*Determining the Decision Matrix;* At this stage, there are m number of decision alternatives to be determined and compared with each other and n number of decision criteria. The decision matrix prepared will be as seen in Equation 7.

$$X = \begin{matrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix} \qquad 7.$$

*Determination of Average Solutions of Criteria;* At this stage, the average solutions of each criterion are determined with the help of Equation 8.

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n} \qquad 8.$$

*Calculation of Average Positive Distance (PDA) and Average Negative Distance (NDA);* At this stage, paying attention to the benefit and cost aspects of the criteria; Average Positive Distance Values (PDA) and Average Negative Distance Values (NDA) are calculated. Accordingly, the Average Positive Distance Values (PDA) of the utility-oriented criteria are calculated with the help of Equation 9. and the Average Negative Distance Values (NDA) with the help of Equation 10. Likewise, Average Positive Distance Values (PDA) of cost-oriented criteria are calculated with the help of Equation 11.and Average Negative Distance Values (NDA) are calculated with the help of Equation 12.

$$PDA_{ij} = \frac{maks.(0; (X_{ij} - AV_j))}{AV_j} \qquad 9.$$

$$NDA_{ij} = \frac{maks.(0; (AV_j - X_{ij}))}{AV_j} \qquad 10.$$

$$PDA_{ij} = \frac{maks.(0; (AV_j - X_{ij}))}{AV_j} \qquad 11.$$

$$NDA_{ij} = \frac{maks.\,(0; (X_{ij} - AV_j))}{AV_j} \qquad 12.$$

*Calculation of Weighted Total Values of PDA and NDA Values;* At this stage, the Weighted Total PDA and NDA values are calculated using the previously determined criteria weights and PDA and NDA values calculated in the previous stage by using another multi-criteria decision making technique by using the Equation 13 and Equation 14.

$$SP_i = \sum_{j=1}^{m} w_j\, PDA_{ij} \qquad 13.$$

$$SN_i = \sum_{j=1}^{m} w_j\, NDA_{ij} \qquad 14.$$

*Normalization of SP and SN Values;* At this stage, the SP and SN values calculated for each alternative are normalized by using the Equation 15 and Equation 16.

$$NSP_i = \frac{SP_i}{maks._i\,(SP_i)} \qquad 15.$$

$$NSN_i = 1 - \frac{SN_i}{maks._i\,(SN_i)} \qquad 16.$$

*Calculation of Evaluation Score;* At this stage, an evaluation score is calculated for all alternatives by using the Equation 17.

$$AS_i = \frac{NSP_i + NSN_i}{2} \qquad 17.$$

*Ranking Alternatives:* At this stage, all alternatives are ordered in descending order according to the calculated Evaluation Score. According to the ranking, it is decided that the alternative with the highest score is the best alternative.

## 4. ANALYSIS and RESULTS

In this study, it is selected 12 commonly used criteria, which most of them are about to green applications, under three main dimensions, based on the literature. These are as follows; Resource Utilization and Green Competence (C1-Green Storage, C2-Green Recycling, C3-Green Production Capacity, C4-Green Packaging, C5-Resource Consumption, C6-Pollution Control), Economic Criteria (C7-Logistics Costs, C8-Product Costs, C9-Delivery Time) and Quality (C10-Error Rate, C11-Warranty and Rights Policies, C12-Environmental Competencies and Documents). The criteria list and their explanations are shown in Table 1.

**Table 1.** Criteria List and Explanations

| Criteria | Explanation |
|---|---|
| C1-Green Storage | It is rated on a scale of 1-9 by evaluating the resource utilization and green competence of alternatives. |
| C2-Green Recycling | |
| C3-Green Production Capacity | |
| C4-Green Packaging | |
| C5-Resource Consumption | |
| C6-Pollution Control | |
| C7-Logistics Costs | It is determined as numeric scale for all alternatives. |
| C8-Product Costs | |
| C9-Delivery Time | |
| C10-Error Rate | It is rated on a scale of 1-9 by evaluating the quality of alternatives. |
| C11-Warranty and Right Policies | |
| C12-Environmental Competencies and Documents | |

Then it is determined 7 alternative suppliers (A1-A7) and firstly it is prepared the decision matrix based on expert opinion. It is also weighted all criteria based on expert opinion. In this stage, of course the weights of criteria can determine by using some other multi-criteria decision-making techniques. And finally the decision matrix prepared as shown in Table 2.

**Table 2.** Decision Matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maks. | Maks. | Maks. | Maks. | Min. | Maks. | Min. | Min. | Min. | Min. | Maks. | Maks. |
| A1 | 6 | 9 | 7 | 8 | 6 | 8 | 76 | 90 | 16 | 7 | 7 | 8 |
| A2 | 8 | 6 | 4 | 9 | 9 | 7 | 78 | 91 | 18 | 5 | 8 | 9 |
| A3 | 9 | 5 | 9 | 7 | 8 | 9 | 80 | 89 | 19 | 9 | 9 | 8 |
| A4 | 7 | 8 | 6 | 7 | 7 | 6 | 81 | 88 | 14 | 7 | 7 | 9 |
| A5 | 9 | 3 | 8 | 9 | 9 | 7 | 76 | 90 | 16 | 4 | 9 | 7 |
| A6 | 8 | 9 | 6 | 8 | 8 | 9 | 74 | 92 | 18 | 8 | 6 | 9 |
| A7 | 6 | 6 | 8 | 6 | 9 | 8 | 82 | 91 | 17 | 6 | 8 | 9 |
| Weight | 0,10 | 0,11 | 0,12 | 0,05 | 0,07 | 0,02 | 0,08 | 0,04 | 0,12 | 0,10 | 0,10 | 0,09 |

As shown in Table 2.; some criteria are benefit-oriented, and some criteria are cost-oriented. All criteria (except C7, C8 and C9) scored as 1 to 9 by an expert, and C7, C8 and C9 scored numerically. And also the weights of criteria determined by expert by doing binary comparison.

Then, as explained in section 3, the application steps of the methods were followed and analyses were made with the help of the COPRAS and EDAS methods, respectively. Accordingly, the normalized decision matrix for the COPRAS method is presented in Table 3.

**Table 3.** Normalized Decision Matrix for COPRAS Method

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,01 | 0,02 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,02 | 0,01 | 0,01 |
| A2 | 0,02 | 0,01 | 0,01 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,01 | 0,01 | 0,01 |
| A3 | 0,02 | 0,01 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,02 | 0,02 | 0,01 |
| A4 | 0,01 | 0,02 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,01 | 0,02 | 0,01 | 0,01 |
| A5 | 0,02 | 0,01 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,01 | 0,02 | 0,01 |
| A6 | 0,02 | 0,02 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,02 | 0,01 | 0,01 |
| A7 | 0,01 | 0,01 | 0,02 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,02 | 0,01 | 0,01 | 0,01 |

Finally, all the parameters of the COPRAS method were calculated and the alternatives were ranked. The calculated parameters and the ranking values of the alternatives are presented in Table 4.

**Table 4.** COPRAS Parameters and Ranking Values

| | S_(+i) | S_(-i) | S_(-min) | S_(-i-Top) | S_(-min)/S_(-i) | S_(-min)/S_(-i) *Top.* | Q_i | N_i | Rank |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,06 | 0,09 | 0,08 | 0,59 | 0,92 | 6,56 | 0,14 | 0,94 | 7 |
| **A2** | **0,06** | **0,08** | | | **1,00** | | **0,15** | **1,00** | **1** |
| A3 | 0,07 | 0,09 | | | 0,88 | | 0,14 | 0,98 | 3 |
| A4 | 0,06 | 0,08 | | | 0,95 | | 0,14 | 0,96 | 5 |
| A5 | 0,05 | 0,08 | | | 0,96 | | 0,14 | 0,94 | 6 |
| A6 | 0,06 | 0,09 | | | 0,90 | | 0,14 | 0,97 | 4 |
| A7 | 0,06 | 0,08 | | | 0,95 | | 0,15 | 0,98 | 2 |

According to COPRAS method the second alternative supplier that involved in the first rank must be chosen.

In the application of the EDAS method, first of all, the total and average values of the criteria are determined according to the values in the decision matrix. Calculated total and average values of criteria are presented in Table 5.

**Table 5.** Total and Average Values of Criteria

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total V. | 53 | 46 | 48 | 54 | 56 | 54 | 547 | 631 | 118 | 46 | 54 | 59 |
| Average V. | 7,57 | 6,57 | 6,86 | 7,71 | 8,00 | 7,71 | 78,14 | 90,14 | 16,86 | 6,57 | 7,71 | 8,43 |

And then by using the same decision matrix and the values that shown in Table 5. İt is calculated the average positive distances, weighted average positive distances, average negative distances, weighted average negative distances respectively and presented Table 6., Table 7., Table 8. and Table 9. respectively.

**Table 6.** Average Positive Distances

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,21 | 0,00 | 0,00 | 0,00 | 0,25 | 0,00 | 0,03 | 0,00 | 0,05 | 0,00 | 0,09 | 0,05 |
| A2 | 0,00 | 0,09 | 0,42 | 0,00 | 0,00 | 0,09 | 0,00 | 0,00 | 0,00 | 0,24 | 0,00 | 0,00 |
| A3 | 0,00 | 0,24 | 0,00 | 0,09 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,05 |
| A4 | 0,08 | 0,00 | 0,13 | 0,09 | 0,13 | 0,22 | 0,00 | 0,02 | 0,17 | 0,00 | 0,09 | 0,00 |
| A5 | 0,00 | 0,54 | 0,00 | 0,00 | 0,00 | 0,09 | 0,03 | 0,00 | 0,05 | 0,39 | 0,00 | 0,17 |
| A6 | 0,00 | 0,00 | 0,13 | 0,00 | 0,00 | 0,00 | 0,05 | 0,00 | 0,00 | 0,00 | 0,22 | 0,00 |
| A7 | 0,21 | 0,09 | 0,00 | 0,22 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,09 | 0,00 | 0,00 |

**Table 7.** Weighted Average Positive Distance

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,02 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,01 | 0,00 |
| A2 | 0,00 | 0,01 | 0,05 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 | 0,00 |
| A3 | 0,00 | 0,03 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| A4 | 0,01 | 0,00 | 0,02 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 | 0,01 | 0,00 |
| A5 | 0,00 | 0,06 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,04 | 0,00 | 0,02 |
| A6 | 0,00 | 0,00 | 0,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 |
| A7 | 0,02 | 0,01 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,00 |

**Table 8.** Average Negative Distances

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,00 | 0,37 | 0,02 | 0,04 | 0,00 | 0,04 | 0,00 | 0,00 | 0,00 | 0,07 | 0,00 | 0,00 |
| A2 | 0,06 | 0,00 | 0,00 | 0,17 | 0,13 | 0,00 | 0,00 | 0,01 | 0,07 | 0,00 | 0,04 | 0,07 |
| A3 | 0,19 | 0,00 | 0,31 | 0,00 | 0,00 | 0,17 | 0,02 | 0,00 | 0,13 | 0,37 | 0,17 | 0,00 |
| A4 | 0,00 | 0,22 | 0,00 | 0,00 | 0,00 | 0,00 | 0,04 | 0,00 | 0,00 | 0,07 | 0,00 | 0,07 |
| A5 | 0,19 | 0,00 | 0,17 | 0,17 | 0,13 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,17 | 0,00 |
| A6 | 0,06 | 0,37 | 0,00 | 0,04 | 0,00 | 0,17 | 0,00 | 0,02 | 0,07 | 0,22 | 0,00 | 0,07 |
| A7 | 0,00 | 0,00 | 0,17 | 0,00 | 0,13 | 0,04 | 0,05 | 0,01 | 0,01 | 0,00 | 0,04 | 0,07 |

**Table 9.** Weighted Average Negative Distance

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0,00 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,00 |
| A2 | 0,01 | 0,00 | 0,00 | 0,01 | 0,01 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,00 | 0,01 |
| A3 | 0,02 | 0,00 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 0,04 | 0,02 | 0,00 |
| A4 | 0,00 | 0,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,01 |
| A5 | 0,02 | 0,00 | 0,02 | 0,01 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 |
| A6 | 0,01 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,02 | 0,00 | 0,01 |
| A7 | 0,00 | 0,00 | 0,02 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 |

Finally, all the parameters of the EDAS method were calculated and the alternatives were ranked. The calculated parameters and the ranking values of the alternatives are presented in Table 10.

**Table 10.** EDAS Parameters and Ranking Values

| | *SPi* | *SNi* | *NSPi* | *NSNi* | *Asi* | Rank |
|---|---|---|---|---|---|---|
| A1 | 0,06 | 0,05 | 0,4860 | 0,5994 | 0,5427 | 4 |
| A2 | 0,09 | 0,04 | 0,6872 | 0,6853 | 0,6863 | 2 |
| A3 | 0,04 | 0,13 | 0,2896 | 0,0000 | 0,1448 | 7 |
| A4 | 0,07 | 0,04 | 0,5702 | 0,6976 | 0,6339 | 3 |
| **A5** | **0,12** | **0,07** | **1,0000** | **0,4435** | **0,7217** | **1** |
| A6 | 0,04 | 0,09 | 0,3334 | 0,3233 | 0,3283 | 6 |
| A7 | 0,05 | 0,04 | 0,4030 | 0,6579 | 0,5304 | 5 |

According to EDAS method the fifth alternative supplier that involved in the first rank must be choosen.

As can be seen, the results of the analysis made by both methods differed from each other. This difference is due to the formulations of the methods. However, at this point, it would be appropriate to prefer a compromised solution. The ranking results obtained by both methods are presented in Table 11.

**Table 11.** Ranking Results for COPRAS and EDAS Methods

| | COPRAS Method Ranking | EDAS Method Ranking |
|---|---|---|
| A1 | 7 | 4 |
| **A2** | **1** | **2** |
| A3 | 3 | 7 |
| A4 | 5 | 3 |
| A5 | 6 | 1 |
| A6 | 4 | 6 |
| A7 | 2 | 5 |

Considering the differences in ranking results, it would be appropriate to choose the second alternative. Because the second alternative is in the first place according to the COPRAS method and the second according to the EDAS method.

## 5. DISCUSSION and CONCLUSION

In this study, the most suitable one among seven alternative green suppliers was selected. For this, first of all, the literature was searched and 12 criteria that are important in green supplier selection were determined. Then, based on expert opinion, the criteria were scored and weighted. Thus, the decision matrix has been obtained.

Since many criteria with different weights gained importance in the study, multi-criteria decision making techniques were used. Multi-criteria decision making techniques have made significant progress in recent years and are widely used in the literature. COPRAS and EDAS methods were used together in the study.

The main reason for choosing the two methods is to determine whether the methods produce reliable results. As a result of the study designed as a hybrid application, different suppliers took the first place according to both methods. Therefore, it is considered that it would not be appropriate to reach a conclusion and make a decision with a single method. It is considered that it would be better to confirm the results obtained with any multi-criteria decision making technique by another method. In the study, this condition was fulfilled and the common solution that ranked first according to the results of both methods was accepted.

Another reason for conducting the study with two methods is to avoid making a possible wrong decision. As a matter of fact, if this study was designed with a single method, the 2nd supplier should have been selected according to the COPRAS method and the 5th supplier should have been selected according to the EDAS method. This situation could have been quite misleading.

It is quite common for multi-criteria decision making techniques to produce different results. Because the formulations of all methods are quite different. However, due to their ease of application and their ease in solving complex problems, they are frequently used in the solution of decision making problems in recent years.

Subsequent studies can be done by considering different criteria and defining different weight values. In addition, different multi-criteria decision making techniques can be used in subsequent studies.

## REFERENCES

Aguezzoul, A., Rabenasolo, B. and Jolly-Desodt, A.M. (2006). “Multicriteria Decision Aid Tool for Third-Party Logistics Providers’ Selection”, ENSAIT, 9 rue de l'Ermitage, BP 30329, 59056 Roubaix Cedex 01, France.

Arslan, R. (2018). Comparison and Integration of Multi-Criteria Decision-Making Methods: An Application on OECD Data, Cumhuriyet University Sosyal Sciences Institude, (Unpublished PhD Thesis), Sivas.

Demirci, A. (2020). *Sağlık Hizmetleri Yönetiminde Çok Kriterli Karar Verme Teknikleri*, Gazi Kitabevi, Ankara.

Demirci, A. (2018). *Health Sciences Research in the Globalizing World*. İçinde R. Efe, E. Alexandrova, N.L. Shapekova, B. Ak ve F. Özcanaslan (Eds.). Analytic Hierarcy Process As Example of Establishment Place Selection (ss. 842-853). St. Kliment Ohridski University Press, Sofia, Bulgaria.

Ghorabaee, M.K., Zavadskas, E.K., Olfat, L. and Turskis, Z. (2015). “Multi-Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS)”, Informatica, Vol: 26, No: 3, 435-451.

Hashemkhani Zolfani, S. and Bahrami, M. (2014). “Investment Prioritizing in High Tech Industries Based On SWARA-COPRAS Approach”, Technological and Economic Development of Economy, Volume: 20 (3), 534-553.

Kaklauskas, A., Zavadskas, E.K., Raslanas, S., Ginevicius, R., Komka, A. and Malinauskas, P. (2006). “Selection of Low-e Windows in Retrofit of Public Buildings by Applying Multiple Criteria Method COPRAS: A Lithuanian Case”, Energy and Buildings 38, 454-462.

Karabasevic, D., Zavadskas, E.K., Stanujkic, D., Popovic, G. and Brzakovic, M. (2018). “An Approach to Personnel Selection in the IT Industry Based on the EDAS Method”, Transformations in Business & Economics, Vol: 17, No: 2 (44), 54-65.

Kuo, R.J., Wang, Y.C. and Tien, F.C. (2010). “Integration of Artificial Neural Network and MADA Methods for Green Supplier Selection”, Journal of Cleaner Production, 18, 1161-1170.

Lee, A.H.I., Kang, H.Y., Hsu, C.F. and Hung, H.C. (2009). “A Green Supplier Selection Model for High-Tech Industry”, Expert Systems with Applications 36, 7917-7927.

Mousavi-Nasab, S.H. and Sotoudeh-Anvari, A. (2017). “A Comprehensive MCDM-based Approach Using TOPSIS, COPRAS and DEA as an Auxiliary Tool for Material Selection Problems”, Material and Design 121, 237-253.

Özbek, A. (2017). Multiple Criteria Decision Making Methods and Problem Solving with Excel, Seçkin Academic and Professional Publications, Ankara.

Podvezko, V. (2011). “The Comperative Analysis of MDCA Methods SAW and COPRAS”, Inzinerine Ekonomika - Engineering Economics, 22 (2), 134-146.

Stanujkic, D., Zavadskas, E.K., Keshavarz Ghorabaee, M. and Turskis, Z. (2017). “An Extension of the EDAS Method Based on the Use of Interval Grey Numbers”, Studies in Informatics and Control, Vol: 26, No: 1, 5-12.

Zavadskas, E.K., Kaklauskas, A. and Sarka, V. (1994). “The New Method of Multicriteria Complex Proportional Assessment of Projects”, Technological and Economic Development of Economy 1 (3), 131-139.