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Sustainable Supply Chain: A Gradation Model That Based on AHP-TOPSIS Method

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Abstract: This study is to determine the sustainable supplier selection criteria through the literature research and to choose the best sustainable supplier with the AHP-Topsis method**.** Nowadays, a sustainable supply chain has become one of the main methods of supply chain management when the growth of information about sustainability in companies bore in mind. Studies about assessment and evaluation of sustainability create the main requirement in sustainable supply chain management. In this study, Economic, social and environmental main criteria and 17 sub criteria have been determined. Weights of criteria are evaluated with methods of Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) As a result of the study, The universe of the research consists of all enterprises affiliated to Bursa Chamber of Industry and Commerce. The research sample consists of a business affiliated to Bursa Chamber of Commerce and Industry. it's been determined that the most important main criterion is "Economical", for the sub criteria, these are "Quality", "Human Rights" and "Green Production". As a result of the analysis, Supplier 4 is chosen as the one who has the highest score among all the existing suppliers of the company.

Keywords: Sustainability, Sustainable Supply Chain, AHP, TOPSIS

Jel Codes: M11, Q01, L22

Sürdürülebilir Tedarik Zinciri: AHP – TOPSİS Yöntemine Dayalı Bir Sıralama Modeli

Öz: *Bu çalışmanın amacı, literatür araştırması yoluyla sürdürülebilir tedarikçi seçim kriterlerini belirlemek ve AHP Topsis yöntemiyle en iyi sürdürülebilir tedarikçi seçimini yapmaktır. Günümüzde, işletmelerde sürdürülebilirlik hakkındaki bilginin büyümesi göz önüne alındığında, sürdürülebilir tedarikçi seçimi, tedarik zinciri yönetiminin ana faktörlerinden biri haline gelmiştir. Sürdürülebilirliğin ölçülmesi ve değerlendirilmesi ile ilgili çalışmalar sürdürülebilir tedarik zinciri yönetiminde temel gereksinimini oluşturmaktadır. Bu çalışmada ekonomik, sosyal ve çevresel ana kriterleri ve 17 alt kriter belirlenmiştir. Kriterlerin ağırlıkları Analitik Hiyerarşi Süreci (AHS) ve Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) yöntemleriyle değerlendirilmiştir. Araştırmanın evreni Bursa Sanayi ve Ticaret Odası'na (BTSO) bağlı tüm işletmelerden oluşturmaktadır. Araştırma örneklemi ise, BTSO'ya bağlı bir işletmeden oluşmaktadır. Çalışma sonucunda en önemli Anakriter "ekonomik" olarak alt kriterler içerisinde "kalite", "insan hakları" ve "yeşil üretim" olarak belirlenmiştir. Analizler sonucunda, işletmenin mevcut tedarikçileri arasında Tedarikçi 4 en yüksek puana sahip tedarikçi seçilmiştir.*

Anahtar Kelimeler*: Sürdürülebilirlik, Sürdürülebilir Tedarik Zinciri, AHP, TOPSİS*

JEL Codes: *M11, Q01, L22*

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GENİŞLETİLMİŞ ÖZET

Araştırma Problemi

Bu çalışma, literatür araştırması yoluyla sürdürülebilir tedarikçi seçim kriterlerini belirlemek amacıyla yapılmıştır. Ayrıca çalışmada, en iyi tedarikçileri seçmek için bu belirlenen ana ve alt kriterler kullanarak AHP-TOPSİS yöntemiyle yeni bir sıralama yöntemi önerilmiştir.

Araştırma Soruları

Sürdürülebilir tedarikçi seçimlerinde en önemli kriter ve alt kriterlerin neler olduğu ve AHP-Topsis yöntemine göre en iyi tedarikçinin belirlenmesidir.

Literatür Araştırması

Küreselleşme ile birlikte artan rekabet koşullarında tedarik zinciri yönetimi, işletmelerin rekabet edebilme durumlarını sürdürebilmek ve dünyanın farklı yerlerinde müşteri taleplerini karşılayabilmek için uygulanmaktadır. Tedarik zinciri yönetiminin verimli bir şekilde uygulayabilmesi, işletmeler tedarikçileriyle bir araya gelerek ihtiyacı olan hammaddeyi istenilen zamanda ve en düşük maliyetle tedarik etmelerine bağlıdır (Öztürk, 2019).

Literatürde, tedarik zinciri yönetimi konusu ile ilgili Analitik Hiyerarşi Süreci (AHP) yönteminin kullanıldığı farklı sektörlerde yapılan çok sayıda çalışma bulunmaktadır. Rajesh (2020) Hindistan bağlamında sürdürülebilir tedarik zincirleri bütünleştirici karar modelinde AHP'yi uygulamıştır. Çalışma sonucunda doğa dostu teknolojilerin standardizasyonu ve yeşil segment boyutunun önemli bir faktör olduğu tespit etmiştir. Hong ve diğ. (2018) Tedarik zinciri dinamik yetenekleri ve kuruluşların sürdürülebilirlik performansları üzerinde sürdürülebilir tedarik zinciri yönetim (TZY) uygulamalarının etkisini araştırmışlardır. Araştırma sonucunda TZY uygulamalarının TZ dinamik yetenekleri üzerinde ekonomik, çevresel ve sosyal sürdürülebilirlik performanslarının üç boyutu üzerinde önemli pozitif etkisi olduğunu gözlemlenmiştir. Sossou ve diğ. (2020) bulanık çok kriterli karar yaklaşımı kullanılarak sürdürülebilir risk yönetimi stratejisi seçimi yapmışlardır. Kannan ve diğ. (2020a), sürdürülebilir tedarik zincirinde yeni bir hibrit yaklaşım araştırması yapmışlardır. Araştırma sonucunda tedarikçi seçiminde çok kriterli karar verme yöntemi kullanarak en iyi tedarikçi seçimini belirlemişlerdir. Vivas ve diğ. (2020) Sürdürülebilir tedarik zinciri optimizasyon ve değerlendirilmesinde Brezilya'da gerçekleştirilenbir vaka çalışmasını AHP yöntemiyle yapmışlardır. Çalışma sonucunda çevresel parametrelerin sosyal yönlerden daha çok ilgili olduklarını belirlemişlerdir. Mastrocinque ve diğ. (2020) yenilenebilir enerji sektöründe sürdürülebilir tedarik zinciri gelişimi için AHP tabanlı çok kriterli bir model üzerinde çalışma yapmışlardır. Önerilerinde fotovoltaik enerji sektöründe sürdürülebilir yatırım kararları almak için güçlü bir araç olduğunu saptamışlardır. Kannan ve diğ. (2020b), sürdürülebilir tedarik zinciri ve firma performansı analizini yapmışlardır. Çalışmalarında, sürdürülebilirliğin çeşitli yönleri ile firma performansı arasında pozitif bir ilişki olduğu doğrulanmakta ve sürdürülebilirlik-firma performans ilişkilerinin gücünün zamanla arttığı ortaya koyulmaktadır.

Yöntem

Bu çalışma Bursa Ticaret ve Sanayi Odasına bağlı otomotiv sektöründe faaliyet gösteren bir işletmede tedarikçi seçim problemi olarak ele alınmıştır. Analizin ilk aşamasında karar verici kişiler seçilmiştir. İşletme çalışanlarından ilgili departmandan otuz uzmana anket çalışması yaptırılmıştır. Anket sonuçları değerlendirilirken Çok Kriterli Karar Verme (ÇKKV) teknikleri kullanılmıştır.

Bulgular ve Sonuç

Araştırmada öncelikle literatürde yer alan sürdürülebilirlik kriterleri belirlenmiş ve bu kriterler işletme yöneticileriyle yapılan görüşme sonucunda nihai haline ulaştırılmıştır. Daha sonra işletmelerden elde edilen veriler excell ofice programı yardımıyla analiz edilmiştir. Ana ve alt kriterlerin öncelik değerleri hesaplanmıştır. Buna göre ana kriterlerden ekonomik kriter 0,644989964, sosyal kriter 0,208631065 ve çevresel kriter 0,14637897 olarak belirlenmiştir. Alt kriterlere bakıldığında ise ekonomik alt kriter için en yüksek değer "kalite" (0,49668776), sosyal alt kriter için en yüksek "insan hakları" (0,25) ve çevresel alt kriter için "yeşil üretim" (0,385816275) şeklindedir. Elde edilen alternatiflerin öncelik değerleri matematiksel işlemler sonrasında tedarikçi seçimi için gerekli olan son değere ulaştırılmıştır. TOPSIS yöntemi ile elde edilen sıralamada Tedarikçi-4 > Tedarikçi-3 > Tedarikçi-2 > Tedarikçi-1 > Tedarikçi-5 şeklinde sıralanmış ve Tedarikçi-4 aranan kriterlere en çok uyum gösteren firma olarak belirlenmiştir. İleride yapılacak çalışmalar için kriterlerin hassasiyetini daha yüksek düzeyde ölçülmesi için ölçek sayısı arttırılabilir. Kriterler ve alt kriterlerin sıralanması PROMETHEE, VİKOR, bulanık DEMATEL, bulanık mantık kullanılarak sürdürülebilir tedarikçi seçimleri yapılabilir.

1. Introduction

The growing competitive environment in recent years is directing companies to produce services that have more outstanding technologies, high quality, and trustworthiness. Intense pressures that consisted of the effect of globalization is made companies dependent on more suppliers day by day to reach their aim and it gave chance to sustainability with the improvement of supplier management to fill the gap between supplier skills and producer expectation (Ndubisi et al., 2005). Nowadays, sustainable progress had become a very conspicuous term in fields such as manufacturing, business development, tourism, and agriculture. In this context, in traditional supply chain management, companies had evaluated suppliers generally according to price, quality, delivery time, and submitted services. (Amindoust et al., 2012). However, because of increasing energy prices, industrial pollution, the absence of compulsory raw material and natural resources, and environmental disasters, nowadays, sustainability is accepted as the most decisive criteria that are considered by companies while choosing the best-fit supplier (Mastrocinque et al., 2020).

When the existing state in the World bore in mind, it is seen that the environmental problems are growing. In this regard, supporting environmental sustainability in operation is seen as the first factor beside that, there is a parallel interest between operators for sustainability and flexibility in producing to get advantages to compete in the future. Sustainable Supply Chain Management (SSCM) is an important way to reach these aims in operation (Solomon, 2007; Bloomfield, 2015; Rajesh, 2020).

Sustainability is amenable for changing and improving environmental aspects until the 2000s and from this point of view, sustainability is a revisable notion, and it has been emphasized mostly on sustainability's environmental dimensions. Solely afterward, the economical and social dimensions had also been added to a sustainable supply chain notion for some developments and transformations. Sustainability is the proper management of the relationship between economical, social, and environmental resources. Based on Sustainability's approach, making economical performance sustainable as well to preserve the companies position in the market represents the economical side of sustainability (Elkington, 2004). Accordingly, sustainable supply chain management (SSCM) is a field that developing in researches and industry. In this regard, it is seen that companies are trying to increase their competition powers by implementing sustainable applications to their products and services. (Vivas et al. 2020, Ansari and Kant, 2017).

This study is done by a literature review to determine the sustainable supplier selection criteria and also in this study a real case application about the best sustainable supplier selection was performed in the automotive supplier companies in Bursa. Moreover, in the review, by using such identified main criteria and sub criteria to choose the best suppliers, the AHP-TOPSIS method with a new gradation method is suggested. The study consists of seven sections. In the first chapter, information was given by leading into the research topic. In the second chapter, it's mentioned the researches oriented to sustainability and sustainable supply chain by scanning literature. The third and fourth chapters, it is telling the methodology of AHP and TOPSIS, which are multi-criteria decision methods. In the fifth chapter, criteria were sorted (ranked) by the research model and the AHP method. In the sixth chapter, there are findings as a result of using AHP-TOPSIS methods. In the last chapter, research was evaluated, findings were commented and suggestions were given to the researchers who will study this topic in the future.

2. Literature Review

In the competition conditions that increased with globalization, supply chain management is being used to maintain companies' competitive positions and to supply with customer demands from all over the world. Operating the supply chain management voluminously depends on the companies to meet with their suppliers and procure the required raw materials at the right time and for the lowest cost.

In literature, there is a lot of research about supply chain management in the different sectors by using the relevant AHP method. Rajesh (2020) has used the AHP sustainable supply chains as a reintegrative decision model in the Indian context. As a result of research, it was determined that the eco-friendly technologies' standardization and green segment dimension are important factors. Hong et al. (2018) researched the Sustainable Supply Chain Management (SSCM) effects on operations of dynamic skills and sustainability performance of organizations. As a result of research, it was observed that SSCM operations have an economical effect on Supply Chain (SC) dynamic skills and important positive effects on three dimensions of environmental and social sustainability performances. Amindoust et al. (2012) developed a new ranking model that basis on fuzzy inference system, in this research has been handled sustainable supply selection in terms of the subjectivity of decision-makers assessment. Their study basis of fuzzy inference system was suggested for supplier selection problem. Sossou et al. (2020) choose the sustainable risk management strategy by using a fuzzy multiple criteria decision approach. Kannan et al. (2020a) researched a new hybrid approach on the sustainable supply chain. As a result of the research, they determined the best supplier choice by using Multi-Criteria Decision-Making Method. Vivas et al. (2020) in the assessments and optimization of a sustainable supply chain, In Brazil, made a case study by using the AHP method. As concluded by the research, they determined that environmental parameters are more related than social aspects. Mastrocinque et al. (2020) in the renewable energy sector, have researched a multiple-criteria model with AHP bounded for the development of a sustainable supply chain. In their suggestion, they determined that there is a powerful tool to make decisions for sustainable investments in the photovoltaic energy sector. Kannan et al (2020b) conducted the sustainable supply chain and company performance analysis. In their research, they confirm that there is a positive relationship between sustainability's' various aspects and company performance and they exhibited that sustainability and company performance relationship strength gets more powerful in time.

2.1. Sustainability

Even if the sustainability notion is being used in the company literature commonly, there is not a common definition. Sustainability is defined with words such as "biological system", "eco-system", "preservation", "social equality". Lots of managers have a common thought who have sustainable company activities, as long as the company maintains its activities, it has to be responsible to the environment, it has to contain various wide base operations and periods (Demirkol, 2020). World commission on environment states in a definement in 1987, "Sustainability is being able to meet the existed human requirements without harming the next generation's lives and without risking their ability to meet their requirements" (WCED, 1987).

International academy papers defined sustainability as permanent human activity and consumption level. In this way, people can ensure goods and services indefinitely. In this respect, in literature, sustainability is defined with three main dimensions which are social, environmental, and economic (Ahi and Searcy, 2013; Mollamohamadi et al., 2013). From a social perspective, sustainability aims to meet human needs without violating their moral and legal rights. Economic sustainability aims to increase production income flow to the highest. Environmental sustainability is defined as companies have to not risk the environment, natural system, and life while they maintain their activities. (Common and Perrings, 1992; Mollamohamadi et al., 2013)

2.2. Sustainable Supply Chain

A supply chain is a network with producers and distributors that supplies raw material, changing these supplied raw materials into semi-finishing and end products and delivers end products to the last consumers (Lee and Billington, 1992). Besides, the supply chain is operations unitary that contribute to supplying the material, conducting the process of these materials turning into the last product, and distributing products to the consumers (Ganeshan and Harrison, 1995).

Sustainable Supply Chain Management (SSCM) ensures the integration of the flow of economical, environmental, and social dimensions and in-house and B2B with innovator and collaborationist approaches to create a sustainable figure (Kannan et al., 2020b). Sustainable supply chain management on the one hand considers sustainability's main factors such as economic, environmental, social, and technology, on the other hand, it can be defined as managing and conducting the tangible, fund, and information flow (Molamohamadi et al., 2013). After choosing the sustainable supplier, by incorporating the social and environmental parameters into the supplier choosing process, economic, social, and environmental criteria were included in this process, as well (Song et al., 2017). A company that has a sustainable supply chain perspective has to keep in touch with suppliers and has to satisfy consumers, government, and stakeholders. Besides, in a sustainable supply chain, sustainability criteria must be considered to choose the right suppliers to produce sustainable products (Molamohamadi et al., 2013).

3. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process is a mathematical theory that was developed by Thomas L. Saaty in the middle of the 1970s and is used to gauging and deciding (Saaty and Niemira, 2006: 1). This method relies on the comparison of criteria and alternatives dyadically. AHP is a method that tries to extrapolate a complicated decision problem by degrading the problem into pairwise comparison (Saaty and Vargas, 2012). AHP allows decision-makers to model complex problems with a hierarchical structure, showing the relationship between the main goal, criteria, sub-criteria, and alternatives to the problem. In AHP, criteria get a pairwise comparison to determine the weights then finding the effects of these weights to the hierarchical structure is on the nail (Wind and Saaty, 1980). The most important feature of the Analytic Hierarchy Process is that it includes both objective and subjective thoughts of the decision-maker in the decision-making process. AHP is a method that is used effectively on lots of decision problems that's been reunited logically with information, experience, a person's thoughts, and intuitions. Thanks to this method, in the decision process, decision-makers can use their craft knowledge and experiments effectively based on their profession (Vargas, 1990:2; Karaatlı et al., 2014).

3.1. Creation of The Hierarchical Structure

In the first step, the problem that is being decided must be understandable and transform into a hierarchical structure in terms of ease of implementation. That's why, the main aim of decision problems is to create criteria, sub criteria, and alternatives in a hierarchical structure (Öztürk, 2019)

3.2. Creation of Pairwise Comparison Matrices

The following steps should be followed to make decisions by establishing priorities with AHP; (Saaty, 2008; Karaatlı et al., 2014)

- The problem should be identified and the type of information being searched should be determined,
- A hierarchical structure should be established with the target of a decision at the top, the criteria at the middle level, and alternatives at the lowest level,
- Pairwise comparison matrices should be created and applied separately for each level,

While creating pairwise comparison matrices, criteria that partaking in the hierarchical steps are used. The criteria are compared with each other by considering the purpose according to the factor in the next step in the hierarchy. At the end of these comparisons, the matrix defined as the pairwise comparison matrix is obtained (Özbek and Erol, 2018). Matrices are created using the 1-9 comparison scale shown in Table 1 suggested by Saaty (1994).

Table 1: Comparison Scale

Score	Definition	Description
1	Equally Important	Both options contribute equally.
3	A Little More Important	Experience and judgment make one criterion superior to another
5	Strongly Important	Experience and judgment make one criterion superior to another
7	Strongly Important	One criterion is considered superior to another and this superiority stands out in implementation.
9	Extremely Important	Evidence that shows one criterion is superior to another has tremendous reliability
2,4,6,8	Intermediate values	Values between two consecutive judgments to be used when accommodation is required

Pairwise comparison is the most important phase of AHP. Relative and absolute measurements are used to obtain pairwise comparisons. By making use of these comparisons, judgments are turned into a matrix in AHP. Aij feature i and j. In general, the pairwise comparison matrix to show the pairwise comparison value of the feature; is an nxn sized square matrix. Aji value is j, by criterion i. is the comparison value of the criterion. This value is obtained by aji = l/aij equality if the aij value is given. This feature is called the provision feature (Saaty, 1994; Saaty and Vargas, 2000).

$$A=\begin{bmatrix} a11 & a12 & \cdots & a1n \\ a21 & a22 & \cdots & a2n \\ \vdots & \vdots & \cdots & \vdots \\ an1 & an2 & \cdots & ann \end{bmatrix}=\begin{bmatrix} 1 & a12 & \cdots & a1n \\ 1/a12 & 1 & \cdots & a2n \\ \vdots & \vdots & \cdots & \vdots \\ 1/a1n & 1/a2n & \cdots & 1 \end{bmatrix}$$

3.3. Normalization of Pairwise Comparison Matrix

After creating pairwise comparison matrices, each element in the matrix is normalized by dividing it by its column sum (equality 1). After the normalized matrix is created, the W priority matrix is obtained, which will have weight values for each factor (Equality 2). (Saaty, 1987; Aktepe and Ersöz, 2014)

$$bij=\frac{a_{ij}}{\sum_{i=1}^{n} a_{iJ}},\quad i,j=1,2,\dots,n \;\dots\dots\dots (1)$$

$$Wi=\frac{\sum_{j=1}^{n} bij}{n}\quad i,j=1,2,3,\dots,n\dots\dots\dots (2)$$

3.4. Calculation of The Consistency Rate

In the fourth stage of AHP, the compliance ratio (CR) is calculated, which indicates whether the created matrices are consistent. If the fit rate (CR) is less than 0.1, it indicates consistency. If it is bigger than 0.1, re-evaluation is required. When calculating the fit rate, firstly, for each row of the comparison matrix, the sum of the weights of the elements in the columns is found, and the normalized matrix values are obtained by dividing the element in each column by these weights. Priorities vector is calculated by taking the average of each line of this normalized matrix. Then, by comparing the priority vector with the matrix, all the priority matrix is obtained. CI (consistency index) and CR (Consistency ratio, Equality 3) are calculated as follows (Saaty, 1980; Mastrocinque et al., 2020; Karaatlı et al., 2014).

$$[t_i]_{nx1} = [X_{ij}]_{nxn} . [W]_{nx1}$$

$$\frac{t_i}{w_i} \quad \forall_i \in n\, for$$

$$\delta_{max=} \frac{\sum_{i=1}^{n} \frac{t_i}{w_i}}{n}$$

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

$$CR = \frac{CI}{RI} \quad \ldots\ldots(3)$$

The random index (RI) value in the equation is given in the table below (Alonso and Lamata, 2006).

Table 2: Random Index

N	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

4. Topsis Method

TOPSIS method developed by Hwang and Yoon in 1981 is a multi-criteria decision-making technique based on the idea of the shortest distance to the positive-ideal solution and the farthest distance to the negative-ideal solution (Marchetti and Wanke, 2020). The first step of this method is the preparation of the decision matrix. In the decision matrix, the options are recorded from top to bottom and towards each alternative, it is written that alternative's features related to the criterion. Therefore, gradation operations are performed using this matrix.

The steps of the Topsis method are listed as follows (Marchetti and Wanke, 2020; Chen, 2019; Dutta et al., 2019; Bertolini et al. 2020; Ramya and Devadas, 2019; Chakravarthi et al., 2020; Bathrinath et al., 2020; De Farias and Ferreira, 2019).

1. Creation of the decision matrix

$$A=\begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m} & \cdots & X_{mn} \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

2. Calculating the Normalized Decision Matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}} \qquad \begin{pmatrix} i = 1, 2, 3, \ldots. \ , m \\ j = 1, 2, 3, \ldots \ \ , \ n \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

3. A weighted normalized decision matrix is calculated as follows

$$V = \left[v_{ij}\right]_{mxn}$$

$$W=\begin{bmatrix} w_{11} & \cdots & w_{m1} \\ \vdots & \ddots & \vdots \\ w_{n1} & \cdots & w_{mn} \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$v_{ij} = w_j * r_{ij} \qquad \begin{pmatrix} i = 1, 2, 3, \ldots. \ , m \\ j = 1, 2, 3, \ldots \ \ , \ n \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Particularly wj: The weight of each j criterion, relative weight values of the normalized decision matrix elements based on purpose found towards importance given to the criteria. Then, the elements in each column of the matrix r given in the equality number 2 are multiplied by the corresponding wij value given in the equality number 3 and the matrix V shown in the equality number 4 is created.

4. Determination of positive ideal (A*) and negative ideal (A¯) solution values

$$A^* = \{v_1, v_2, v_3, \ldots, v_n\} = \begin{Bmatrix} (max_i v_{ij} | j \in J), (min_i v_{ij} | j \in J), \\ i = 1,2, \ldots m \end{Bmatrix} \ldots.. (8)$$

$$A^- = \{v_1, v_2, v_3, \ldots, v_n\} = \begin{Bmatrix} (min_i v_{ij} | j \in J), (max_i v_{ij} | j \in J), \\ i = 1,2, \ldots m \end{Bmatrix} \ldots. (9)$$

J = Maximized factor group (benefits)
J = Minimized factor group (Costs)

5. The distinction between alternatives is measured. Distance values to positive S_i^+ ideal and negative S_i^- ideal solutions are calculated for each alternative.

$$S_i^+ = \sqrt{\sum_{J=1}^{n}(v_{ij} - v_j{}^+)^2} \qquad i = 1, 2, \dots, m; 0 < S_i^+ < 1 \dots\dots\dots (10)$$

$$S_i^- = \sqrt{\sum_{J=1}^{n}(v_{ij} - v_j{}^-)^2} \qquad i = 1, 2, \dots, m; 0 < S_i^- < 1 \dots\dots\dots (11)$$

6. Relative proximity to positive ideal solution;

$$C_i^+ = \frac{S_i^-}{(S_i^+ + S_i^-)} \dots\dots\dots (12)$$

Where Ci+ value takes a value in the range of 0≤ Ci+ ≤1 Among the alternatives evaluated, the alternative with the highest coefficient of proximity is considered as the best.

5. Implementation of AHP Method

This study has been handled as a supplier selection problem in a business operating in the automotive sector affiliated to Bursa Chamber of Commerce and Industry. In the first stage of the analysis, decision-makers were selected. These surveys were conducted by thirty experts from the relevant department among the business employees. Evaluation of the survey results MCDM techniques were used.

In the first step of AHP, the decision problem's main aim, criteria, sub criteria, and alternatives were created in a hierarchical structure and shown in Figure1.

The main criteria are determined respectively as environmental, social, and economic. Sub criteria are; under the environmental main criterion, "Environmental handling and packaging (C1)", "Eco-friendly production (C2)" and "Reverse logistics (C3)", "Emission (C4)" and "Cleaner technology usability (C5)". Under the social main criteria; "Human Rights (S1)", "Number of Employees (S2)", "Social Responsibility (S3)", "Continuous improvement (S4), "Occupational Health and Safety (S5), "Wages and Working Hours (S6) and "Education of Employees (S7). Under the economical main criteria; "Quality (E1)", "Cost (E2)", "On-Time Delivery (E3)", "Flexibility (E4)", "Distance (E5)" and Supplier (P).

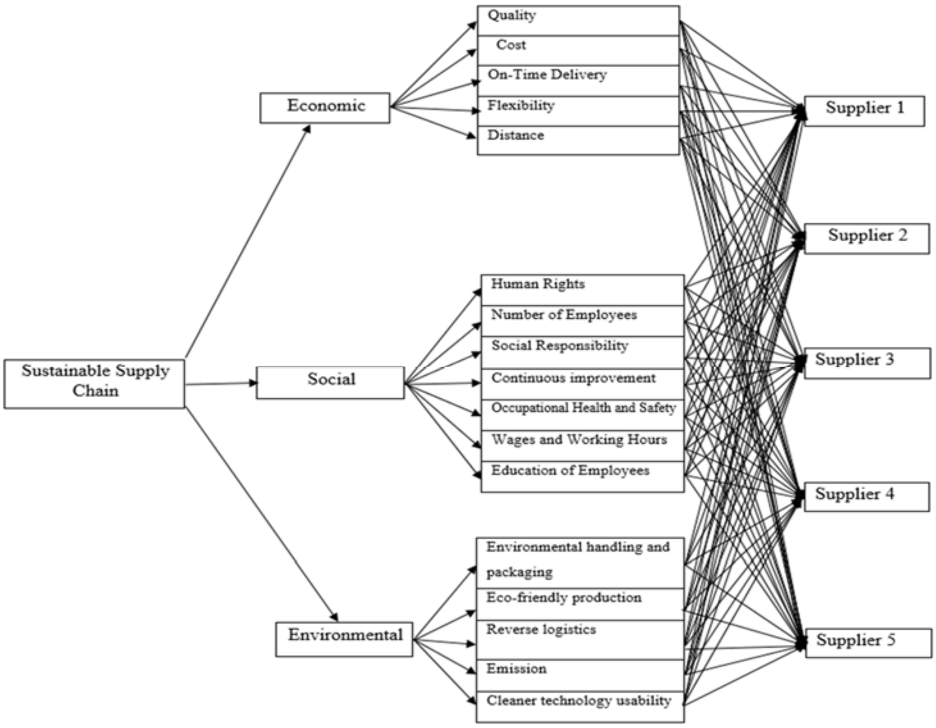


Figure 1 *The Structure of AHP-TOPSİS*

In the second and third steps of AHP, pairwise comparison matrices were created, relative priorities were determined and the consistency rates of the matrices were calculated. Geometric averages of pairwise comparison values obtained by taking the opinions of experts in the enterprise were calculated and a common opinion was formed. Comparing the main criteria with each other, it is seen that the most important criterion is economical (0,645). The economical criterion is followed by social (0,209) and environment (0,146). The pairwise comparison matrix was found to be below 0.10 with a consistency rate of 0,09557. (Table 3).

Table 3: *AHP Matrix for Weighting Criteria*

	Economic	Social	Environmental	Priorities
Economic	1,00	4,510115	3,335326	0,644989964
Social	0,221724	1,00	1,983465	0,208631065
Environmental	0,299821	0,504168	1,00	0,14637897
Consistency Ratio: 0,09557				

Pairwise comparison of sub criteria, relative priority values, and consistency ratios are given in Table 4-6 According to this, quality in terms of economical criterion (0,49668776), human rights in terms of social criterion (0,25), green production in terms of environmental criterion (0,385816275) are seen as the most important sub criteria. For all pairwise comparisons, the consistency rate was found to be below 0,10.

Table 4: *Economic Dimension*

	E1	E2	E3	E4	E5	Priorities
E1	1,00	4,457377	4,878456	4,783803	6,232772	0,49668776
E2	0,224347	1,00	3,429932	2,970184	4,558492	0,22335133
E3	0,204983	0,291551	1,00	2,543375	5,134134	0,14816851
E4	0,209039	0,336679	0,393178	1,00	2,69919	0,08651698
E5	0,160442	0,219371	0,194775	0,370482	1,00	0,04527542
Consistency Ratio: 0,099702						

Tablo 5: *Social Dimension*

	S1	S2	S3	S4	S5	S6	S7	Priorities
S1	1,00	3,54	2,84	2,83	0,99	2,58	2,73	0,25
S2	0,2826	1,00	0,31	0,24627	0,2634	0,23274	0,27169	0,04
S3	0,3521	3,22	1,00	0,29744	0,2462	0,30687	0,40449	0,07
S4	0,3531	4,06	3,36	1,00	0,40	1,08	0,94	0,13
S5	1,0054	3,80	4,06	2,47221	1,00	1,22	1,04	0,21
S6	0,3876	4,30	3,26	0,92399	0,82	1,00	0,29	0,13
S7	0,3663	3,68	2,47	1,06355	0,96	3,45	1,00	0,17
Consistency Ratio: 0,07								

Table 6: *Environmental Dimension*

	C1	C2	C3	C4	C5	Priorities
C1	1,00	0,19	0,20	0,18	0,54	0,051735575
C2	5,19	1,00	3,82	1,82	3,45	0,385816275
C3	4,89	0,26	1,00	0,22	3,19	0,16706605
C4	5,57	0,55	4,45	1,00	2,75	0,305239862
C5	1,84	0,29	0,31	0,36	1,00	0,090142237
Consistency Ratio:0,086703						

6. Implementation of Topsis Method

In operation, the TOPSIS method was carried out in six steps.

Step 1: Creation of ıthe decision matrix

The decision matrix is formed according to the geometric average of the scores ranging from 1-10 given by the decision-makers to the suppliers towards the criteria determined by the decision-makers (Table 7). decision-makers consist of a team of thirty experts, consisting of merchandising, production, and supply managers of the company.

Table 7: *Decision Matrix*

	E1	E2	E3	E4	E5	S1	S2	S3
P1	0,37	0,15	0,15	0,46	0,89	0,78	0,89	0,78
P2	1,66	1,56	1,52	1,78	1,89	1,88	2,88	2,56
P3	3,33	1,25	2,45	3,46	3,89	3,64	3,88	2,00
P4	4,14	4,25	3,35	4,56	3,65	3,88	1,89	2,88
P5	0,12	0,45	0,54	0,21	0,14	0,17	0,48	0,45

Table 7 (Continued)

	S4	S5	S6	S7	C1	C2	C3	C4	C5
P1	0,64	0,82	0,92	0,46	0,25	0,58	0,88	0,61	0,33
P2	1,56	1,45	1,78	1,98	2,07	2,35	2,36	2,46	1,87
P3	1,45	1,86	1,78	1,56	1,78	2,31	2,56	2,89	2,99
P4	2,78	2,99	2,45	2,65	2,45	2,01	3,58	3,21	3,31
P5	0,78	0,88	0,98	0,56	0,66	0,86	0,54	0,62	0,66

Step 2: Normalization of decision matrix

In this step, the normalization of the decision matrix was made by dividing each value into the columns by the square root of the sum of the squares of all values in the relevant column and reducing them to a single denominator (Table 8).

Table 8: *Normalized Decision Matrix*

	E1	E2	E3	E4	E5	S1
P1	0,07	0,0317759	0,03366793	0,07646588	0,15530985	0,13687223
P2	0,297495817	0,3304699	0,34116840	0,29588974	0,32981530	0,329897169
P3	0,596783777	0,2647996	0,54990959	0,57515646	0,67882621	0,638737072
P4	0,741947398	0,9003186	0,75191720	0,75800967	0,63694490	0,680851604
P5	0,021505722	0,0953278	0,12120456	0,03490834	0,02443076	0,029831127

Table 8: (Continued)

	S2	S3	S4	S5	S6	S7
P1	0,1683644	0,1759199	0,17560628	0,205327502	0,244607329	0,123374065
P2	0,5448197	0,5773781	0,42804032	0,363079119	0,473262006	0,53104489
P3	0,7339933	0,4510766	0,39785799	0,46574287	0,473262006	0,418399004
P4	0,3575379	0,6495504	0,76278981	0,748694184	0,651399952	0,710741898
P5	0,0908032	0,1014922	0,21402016	0,220351465	0,260559981	0,150194514

Table 8: (Continued)

Step 3: Creation of the weighted decision matrix

The weighted decision matrix (Table 10) was created by multiplying the normalized decision matrix values created in the previous step by the weight coefficients (W) (Table 9) of the criteria obtained in AHP.

	C1	C2	C3	C4	C5
P1	0,06692559	0,145115	0,172564	0,120883	0,067449
P2	0,554143881	0,587965	0,462784	0,487494	0,382209
P3	0,476510198	0,577957	0,502003	0,572706	0,611126
P4	0,655870777	0,502898	0,70202	0,63612	0,676531
P5	0,176683556	0,21517	0,105891	0,122864	0,134897

Table 9: Criteria Weight Values

W	0,32035846	0,144059294	0,095567154	0,055802556	0,029202177	0,052157766

Table 9: (Continued)

W	0,008345243	0,014604175	0,027122038	0,043812524	0,027122038	0,035467281

Table 9: (Continued)

W	0,007573062	0,056475	0,024455	0,044681	0,013195

Table 10: Weighted Decision Matrix

P1	0,02	0,00	0,00321754	0,0042669	0,0045353	0,0071389
P2	0,09530530	0,0476072	0,03260449	0,0165114	0,0096313	0,0172066
P3	0,19118473	0,0381468	0,05255329	0,0320952	0,0198232	0,0333150
P4	0,23768912	0,1296992	0,07185858	0,0422988	0,0186001	0,0355116
P5	0,00688954	0,0137328	0,01158317	0,0019479	0,0007134	0,0015559

Table 10: (Continued)

P1	0,0014050	0,0025691	0,0047628	0,00899591	0,00663424	0,00437574
P2	0,0045466	0,0084321	0,01160932	0,01590741	0,01283583	0,01883471
P3	0,0061253	0,0065876	0,01079072	0,02040537	0,01283583	0,01483947
P4	0,0029837	0,0094861	0,02068841	0,03280218	0,01766729	0,02520808
P5	0,0007577	0,0014822	0,00580466	0,00965415	0,00706691	0,00532699

Table 10: (Continued)

P1	0,000506832	0,008195	0,00422	0,005401	0,00089
P2	0,004196566	0,033206	0,011317	0,021782	0,005043
P3	0,003608641	0,03264	0,012276	0,025589	0,008064
P4	0,00496695	0,028401	0,017168	0,028422	0,008927
P5	0,001338036	0,012152	0,00259	0,00549	0,00178

Step 4: Determination of positive and negative ideal solutions

In the weighted decision matrix, ideal and negative ideal solution values were determined by selecting a positive and negative solution for an ideal solution from the relevant column of each criterion (Table 11).

Table 11: Positive and Negative Ideal Solutions

a+	0,2376891	0,12969927	0,0718585	0,04229887	0,01982320	0,03551169
a-	0,0068895	0	0,0032175	0,00194797	0,00071343	0,00155592

Tablo 11: (Continued)

a+	0,00612535	0,00948614	0,02068841	0,03280218	0,01766729	0,02520808
a-	0,00075777	0,00148221	0,0047628	0,00899591	0,00663424	0,00437574

Tablo 11: (Continued)

a+	0,00496695	0,033206	0,017168	0,028422	0,008927
a-	0,000506832	0,008195	0,00259	0,005401	0,00089

Step 5: Calculation of distinction criteria

Positive ideal and negative ideal values were subtracted from the values in the column that belong to each criterion and positive and negative ideal solution distance values were determined respectively (Table 12 and Table 13).

Table 12: *Distance Values to Positive Ideal Solution*

P1	0,046849035	0,015655427	0,004711593	0,001446424	0,000233717	0,000805013
P2	0,020273153	0,006739098	0,001540884	0,000664994	0,000103874	0,000335073
P3	0,002162659	0,008381847	0,000372694	0,000104115	5,86871E-20	4,82505E-06
P4	1,56712E-19	3,07501E-21	8,38488E-18	1,68206E-19	1,49579E-06	2,90086E-20
P5	0,053268449	0,013448208	0,003633126	0,001628195	0,000365183	0,001152995

Table 12: (Continued)

P1	2,22813E-05	4,78447E-05	0,000253625	0,000566738	0,000121728	0,000434
P2	2,49229E-06	1,11095E-06	8,24299E-05	0,000285433	2,33431E-05	4,06E-05
P3	5,87766E-20	8,40156E-06	9,79644E-05	0,000153681	2,33431E-05	0,000108
P4	9,86972E-06	3,26881E-24	1,61124E-19	1,35948E-19	1,99195E-19	1,16E-19
P5	2,88109E-05	6,4063E-05	0,000221526	0,000535831	0,000112368	0,000395

Table 12: (Continued)

						Total	Si*
P1	1,99E-05	0,00062	0,000168	0,00053	6,46E-05	0,07249044	0,269240498
P2	5,93E-07	2,2E-13	3,42E-05	4,41E-05	1,51E-05	0,03017142	0,173699236
P3	1,85E-06	3,2E-07	2,39E-05	8,03E-06	7,45E-07	0,01145115	0,107010076
P4	1,02E-19	2,31E-05	1,76E-14	9,29E-14	6,05E-14	3,44504E-05	0,005869446
P5	1,32E-05	0,00044	0,000213	0,000526	5,11E-05	0,07604888	0,275769619

Table 13: Negative distance values to the ideal solution

P1	0,000206	2,09546E-05	1,75215E-18	5,37784E-06	1,46073E-05	3,11702E-05
P2	0,007817	0,002266451	0,00086359	0,00021209	7,95288E-05	0,000244947
P3	0,033964	0,001455182	0,00243401	0,00090885	0,00036518	0,001008645
P4	0,053268	0,016821901	0,00471159	0,00162819	0,00031993	0,001152995
P5	1,6235E-20	0,000188592	6,99837E-05	1,46251E-19	2,2959E-19	2,62932E-21

Tablo 13: (Continued)

P1	4,18953E-07	1,18147E-06	2,33415E-19	1,06674E-21	1,47015E-19	1,22E-19	1,12E-19
P2	1,43556E-05	4,83014E-05	4,68749E-05	4,77688E-05	3,84596E-05	0,000209	1,36E-05
P3	2,88109E-05	2,6065E-05	3,63358E-05	0,000130176	3,84596E-05	0,000109	9,62E-06
P4	4,95492E-06	6,4063E-05	0,000253625	0,000566738	0,000121728	0,000434	1,99E-05
P5	2,16088E-19	1,40837E-19	1,08548E-06	4,33277E-07	1,87202E-07	9,05E-07	6,91E-07

Tablo 13: (Continued)

					Total	Si-
P1	1,66E-13	2,66E-06	1,52E-14	4,62E-16	0,000282382	0,016804225
P2	0,000626	7,62E-05	0,000268	1,72E-05	0,012889662	0,113532648
P3	0,000598	9,38E-05	0,000408	5,15E-05	0,041665974	0,204122447
P4	0,000408	0,000213	0,00053	6,46E-05	0,080583435	0,283872217
P5	1,57E-05	1,88E-13	7,86E-09	7,92E-07	0,000278333	0,016683321

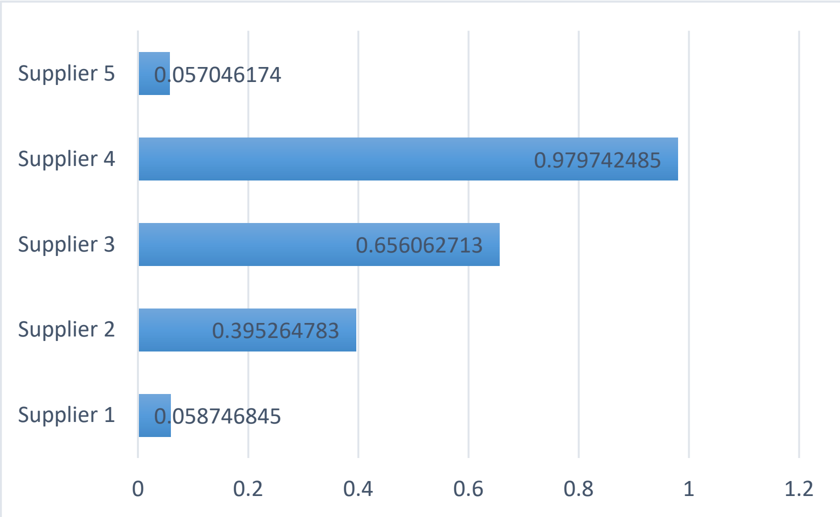
Step 6: Calculation of the relative proximity to the ideal solution

For each alternative value, proximity was found according to the ideal solution by dividing the negative ideal solution value by the sum of its value and the positive ideal solution value of the same alternative (Table 14).

Table 14: Ranking of Selected Supplier According to TOPSIS Method

	Si+	Si-	Ci	Rank
P1	0,269240498	0,016804225	0,058746845	4
P2	0,173699236	0,113532648	0,395264783	3
P3	0,107010076	0,204122447	0,656062713	2
P4	0,005869446	0,283872217	0,979742485	1
P5	0,275769619	0,016683321	0,057046174	5

Table 15: *Sorting by Supplier Score*



When the proximity coefficients of alternatives are examined in the TOPSIS method; Supplier-4 Company 0.979742485, Supplier-3 company 0,656062713, Supplier-2 company 0,395264783, for Supplier-1 company 0,058746845 and Supplier-5 it's 0,057046174. According to the Topsis method, the supplier companies' sorting fis listed as Supplier-4> Supplier-3> Supplier-2> Supplier-1> Supplier-5. According to the results obtained, it has been found suitable for the company working with the Supplier-4 company which has the highest coefficient.

Conclusion

Sustainability is a large scale strategy based on resource permanency that produces the most appropriate solutions covering all segments of society. It refers to having a holistic approach when considering solutions as it considers both natural balance and future generations. From a social perspective, sustainability aims to meet human needs without violating their moral and legal rights. Economical sustainability aims to increase production income flow to the highest. Environmental sustainability is defined as companies have to not risk the environment, natural system, and life while they maintain their activities.

In this study, it was focused on how the selection of suppliers, one of the most important elements of the supply chain, can be realized for sustainability. At this point, the AHP-Topsis method which is frequently used in the literature was used to select the most suitable supplier. In the research, firstly, sustainability criteria in the literature were determined and these criteria were finalized as a result of the meeting with the business managers. After that, the data obtained from the companies were analyzed with the help of the excel office program. Priority values of main and sub criteria were calculated. The economic criterion 0,644989964, social criterion 0,208631065, and environmental criterion 0,14637897 is calculated as a main criteria. When the sub criteria are analyzed, the highest value for the economic sub criterion is "quality" (0,49668776), the highest for the social sub criterion is "human rights" (0,25) and for the environmental sub criterion, it is "green production" with (0,385816275). Priority values of the alternatives obtained were reached to the final value required for supplier selection after the mathematical operations. In the ranking obtained by the TOPSIS method, the supplier-4> supplier-3> supplier-2> supplier-1> supplier-5 were listed and the supplier-4 was determined as the company that best complies with the criteria.

When the literature is analyzed, it is seen that there are some similar studies on sustainable supplier selection. Kannan et al. (2020b) accepted in their study carried out in 2020, priorities of many criteria were determined based on economic, social, and circular factors as three dimensions of sustainability. It is seen that the economic criterion has the highest value. Vivas et al. (2020) examined the economical, environmental, and social sustainability with AHP and PROMETHEE methods. They emphasized that environmental criteria are more important than other criteria. It is seen that emissions are the most important among the environmental criteria. Mastrocinque et al. (2020) in their study on an AHP-based multi-criteria model for sustainable supply chain development in the renewable energy sector, made choices on a country basis. It was observed that the highest value in the selection of suppliers in the renewable energy sector belongs to Germany. In the research of Luthra et al. (2017) according to the criteria of sustainable supplier selection, "Environmental costs", "Product quality", "Product price", "Occupational health and safety systems", and "Environmental qualifications" are listed as five sustainable supplier selection criteria.

For further studies, the number of scales can be increased to measure the sensitivity of criteria at a higher level. By using PROMETHEE, SWARA, COPRAS, VIKOR, fuzzy DEMATEL, fuzzy logic, sorting criteria, and sub criteria can be made and sustainable supplier selections can be done.

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