İnsan ve Toplum Bilimleri Araştırmaları Dergisi
Journal of the Human and Social Science Researches
[2147-1185]

10 th Years

[itobiad], 2021, 10 (2): 1118-1139

A Hybrid Multi-Criteria Decision-Making Method Proposal For The Solution Of The Packaging Supplier Selection Problem

Ambalaj Tedarikçi Seçim Probleminin Çözümü İçin Hibrit Çok Kriterli Bir Karar Verme Yöntemi Önerisi

Video Link: https://youtu.be/kpqilBJvR8o

Özlem KARADAĞ ALBAYRAK

Dr. Öğr. Üyesi, Kafkas Üniversitesi İktisadi ve İdari Bilimler Fakültesi

Assistant. Prof., Kafkas University Faculty of Economics and Adminitrative Sciences

ozlemkaradagalbayrak@gmail.com / Orcid ID: 0000-0003-0832-0490

Makale Bilgisi / Article Information

Makale Türü / Article Type	: Research Article
Geliş Tarihi / Received	: 03.12.2020
Kabul Tarihi / Accepted	: 14.02.2021
Yayın Tarihi / Published	: 01.06.2021
Yayın Sezonu	: Nisan-Mayıs-Haziran
Pub Date Season	: April-May-June

Atıf/Cite as: Karadağ Albayrak, Ö . (2021). A Hybrid Multi-Criteria Decision-Making Method Proposal For The Solution Of The Packaging Supplier Selection Problem . İnsan ve Toplum Bilimleri Araştırmaları Dergisi , 10 (2) , 1118-1139 . Retrieved from http://www.itobiad.com/tr/pub/issue/62559/835506

İntihal /Plagiarism: Bu makale, en az iki hakem tarafından incelenmiş ve intihal içermediği teyit edilmiştir. / This article has been reviewed by at least two referees and confirmed to include no plagiarism. http://www.itobiad.com

A Hybrid Multi-Criteria Decision-Making Method Proposal for the Solution of the Packaging Supplier Selection Problem

Abstract

Selection or evaluation problems are solved by looking at the different performance factors of the suppliers along the supply chain and by making comparisons with each other, and it is ensured that important preliminary information about the suppliers is obtained. This study has been prepared in order to choose the most suitable supplier among the suppliers that provide / are candidates to provide packaging material for an enterprise producing goods

Decision processes may not always have precision due to differences of opinion arising from human behaviour. When supplier selection problems are solved, many criteria, such as different opinions of decision-makers and their conflict of interests are considered. Multi-Criteria Decision Making (MCDM) techniques are highly effective in finding solutions to such problems. The goal of this article was to find a solution to packaging supplier selection problem of a manufacturing company in a fuzzy environment. To this end, eight suppliers were examined in line with 15 evaluation criteria. The opinions of 4 different decision-makers were taken during decision-making process. The solution of the problem was based upon a mixed model consisting of Fuzzy Analytic Hierarchy Process (F-AHP), used to determine the weights of the criteria, and Fuzzy Weighted Aggregated Sum Product Assessment (F-WASPAS), utilised to make preference among alternatives. At the end of the analysis on the determination of the criteria weights, the most appropriate supplier selection was determined as the delivery date and price, respectively, the two factors most influencing the construction phase. As a result of the evaluation made, A2 was specified to be the most proper supplier. Sensitivity analysis was performed to identify the effectiveness of the results. A2 was determined to be the most proper supplier according to the selection results obtained by MARCOS, MABAC, SAW, ARAS, TOPSIS, EDAS methods.

Keywords: Fuzzy Set, Supplier Selection Problems, Multiple-criteria Decision-Making (MCDM), F-WASPAS, F-AHP.

Ambalaj Tedarikçi Seçim Probleminin Çözümü İçin Hibrit Çok Kriterli Bir Karar Verme Yöntemi Önerisi

Öz

Tedarik zinciri boyunca seçim veya değerlendirme problemleri tedarikçileri farklı performans faktörlerine göre değerlendirerek ve birbirleriyle karşılaştırılmaları yapılarak çözülür. Bu şekilde tedarikçiler ile ilgili önemli ön bilgilerin elde edilmesini sağlanmış olur. İşletmeler rekabet güçlerini sürdürebilmek için tedarikçi seçimi için hızlı, etkin ve başarılı yöntemleri kullanmak isterler. Bu çalışma mal üretimi yapan bir işletmenin kendisine ambalaj malzemesi sağlayan/sağlamaya aday tedarikçiler içinde en uygun olanı seçmek için bir yöntem sunmuştur. Günümüz küresel rekabet ortamında, işletmeler piyasaya sundukları ürünleri için kullanacakları malzemelerin seçimine ilişkin kararları alınırken maliyetin azaltabilecek ve piyasada rekabet üstünlüğünü sağlayabilecek alternatifleri tercih ederler.

İnsan davranışından kaynaklanan görüş ayrılıkları nedeniyle karar süreçleri her zaman kesin bilgiler içermezler. Tedarikçi seçim problemleri çözülürken, karar vericilerin farklı görüşleri ve çıkar çatışmaları gibi birçok etken dikkate alınır. Çok Kriterli Karar Verme (ÇKKV) teknikleri, bu tür sorunlara çözüm bulma konusunda oldukça etkilidir. Bu makalenin amacı, bulanık bir ortamda bir imalat işletmesinin ambalaj tedarikçisi seçim sorununa bir çözüm sunmaktır. Bu amaçla sekiz tedarikçi 15 değerlendirme kriterine göre değerlendirilmiştir. Kararalma sürecinde 4 farklı karar vericinin görüşü başvurulmuştur. Sorunun çözümü, kriterlerin ağırlıklarını belirlemek için kullanılan Bulanık Analitik Hiyerarşi Süreci (F-AHP) ve alternatifler arasında tercih yapmak için kullanılan Ağırlıklı Birleşik Toplu Çarpım Değerlendirmesinden (F-WASPAS) oluşan karma bir modele dayanmaktadır. Kriterler ağırlıklarının belirlenmesine ilişkin yapılan analiz sonunda, en uygun tedarikçi seçimi problemleri analiz edilirken en çok etkili olan iki faktör sırası ile teslim tarihi ve fiyat olarak belirlenmiştir Yapılan değerlendirme sonucunda A2 en uygun tedarikçi olarak önerilmiştir. Sonuçların etkinliğini belirlemek için duyarlılık analizi yapılmıştır ve yine MARCOS, MABAC, SAW, ARAS, TOPSIS, EDAS yöntemleriyle elde edilen seçim sonuçlarına göre A2 en uygun tedarikçi olarak belirlenmiştir.

Anahtar Kelimeler: Bulanık Set, Tedarikçi Seçim Problemi, Çok Kriterli Karar Verme Teknikleri (ÇKKV), F-WASPAS, F-AHP.

Introduction

Today, all actors involving in the production process of goods or services are indeed members of a supply chain. A supply chain consists of the activities associated with the transformation and flow of goods and services as well as the information flow from raw material to end user (Öztürk and Özçelik, 2014: 131). Decision-makers take into consideration many factors in solutions to supply selection problems during a supply chain. In traditional supply chain management, quality, cost and delivery are accepted to be common and frequently used criteria for a potential supplier (Sen et. al, 2018: 545). Nowadays, selection and evaluation problems in the supply chain are handled together with the factors regarding sustainability. These factors generally consist of economic, social and environmental ones within the scope of sustainability.

In order to select proper suppliers during a supply chain, there are two primary criteria involving the importance level of selection criteria and the performance of suppliers in accordance with these criteria (Ordoobadi, 2009: 314). The groups of more than one individuals are effective in selection problems and decision-making problems. Group decision-making process refers to the generation of a solution (an option or a set of options) from individual choices related to some options. The solution agreed mostly consists of the selections reflecting "best" preferences of the majority of related individuals (Szmidt and Kacprzyk, 2002: 1037).

Fuzzy decision processes refer that goals and/or restrictions create alternative classes of which boundaries are not sharply defined (Bellman and Zadeh, 1970: 141). When taking a decision in an uncertain environment, the result of decision making is affected significantly by uncertain and indefinite subjective judgments (Wu and Lee, 2007: 501).

Fuzzy set theory helps in coping with the complexity of human thought and expression in decision making (Liou et. al; 2008: 22, Sen et. al: 2018: 547). In addition, the use of fuzzy numbers provides analysts with involving inherent uncertainty of language variables into decision-makers process (Ahmed and Kılıç, 2015: 1).

Multi-criteria decision making (MCDM) methods are very beneficial tools for taking daily decisions in different fields (Stevic et. al., 2020: 1). MCDM techniques were utilised for problem solution since there were more than one decision-makers in the company where the administration would be carried out and different alternatives were evaluated according to different criteria. To this end, the efficiency of F-AHP and F-WASPAS model, a hybrid model, was investigated related to problem solution. In the company where administration was conducted, 8 different suppliers were evaluated according to 15 criteria. In the company where administration was performed, the opinions of four different decision-makers regarding the inclusion of this material in the production process were considered. The importance levels, that is weights of the evaluation criteria, were determined by utilising the F-AHP method. Next, F-WASPAS method was specified to be the most proper within all alternatives.

MCDM techniques are frequently used in the solution of supplier selection problems. Sun (2010: 7745) evaluated the performances of the world's four largest computer manufacturers by hybrid F-AHP and F-TOPSIS method. In an integrated fuzzy environment, Yücesan et. al (2019: 1) conducted the most proper green supplier selection by using Best-Worst method (BWM) and TOPSIS methodology. Kaushik et al (2020: 1) selected online fashion Retail company by BWM, VIKOR methods. Gümüş (2009: 4067) evaluated hazardous waste transportation companies by F-AHP-TOPSIS methods. Xiong et. Al (2020: 1) utilised WASPAS, BWM and TOPSIS methods in the Intuitionistic Fuzzy Environment for the selection of Resilient-Green Supplier Selection. Jain et al. (2020: 1) found a solution to the sustainable supplier selection problem by F-AHP and TOPSIS methods. Prajapati (2020: 301) integrated F-AHP and RAD methods for outsourcing performance measurement. Ortiz-Barrios et al. (2020: 1) selected proper elevator suppliers by F-AHP and DAMETAL methods.

Turkis et al. (2015: 873) solved the problem of work-site selection by Fuzzy AHP-WASPAS methods. Ayyıldız and Gümüş (2020: 36109) used the F-AHP and F-WASPAS methods in the problem of petrol station location selection. The fuzzy WASPAS method is also used in the solution to supplier selection problems (Petrovic et al. (2019: 455), Xiong et. al. (2020: 1), Singh and Modgil (2020: 243).

The factors (criteria) to be used in this study for the evaluation of suppliers were determined in accordance with the literature review and after interviewing with decision-makers. The criteria to be used are provided in Table 1.

Table 1. Description of Criteria

Criteria	Criteria' Codes	Criteria Description	References
ISO 14001 certificate	K1	Certified requirement of the environmental management system	Zue et al.. (2010: 309), Kuo (2010: 1166), Hsu (2009: 256), Humphreys (2003: 350), Khan et al. (2018: 971)
Cycle time	K2	Time between placing an order and receiving it	Kuo et al. (2010: 1166)
Flexibility	K3	Speed of response to customer demand changes	Tseng and Chiu (2013), Kuo et al. (2010: 1166), Yücesan et al. (2019: 181) , Khan et al. (2018: 971), Ortiz-Barrios et

			al.(2020: 14)
Technical Capacity	K4	The ability to meet customers' orders	Kuo et al. (2010: 1166), Khan et al. (2018: 971)
Experience	K5	Experience and working time in the industry	Prajapati et al. (2020: 307), Ortiz-Barrios et al.(2020: 14)
Relationship Level	K6	Ease of communication between supplier and customer	Tseng and Chiu (2013: 24),
ISO 9001	K7	The importance given to the quality function in management and organization for companies with ISO 9001 certificate. ISO-9001 certification is one of the material conditions to participate in the tender held by the state in Turkey.	Kuo et al. (2010: 1166), Yücesan et. al (2019: 181), Ortiz-Barrios et al.(2020: 14)
Refund or Waste Rate	K8	Rreturn and rejection rates determined by input quality control	Kuo et al. (2010: 1166), Mafakheri et al. (2011: 54), Yücesan et. al (2019: 181)
R&D capability	K9	Capability of developing new designs and speed of development	Kuo et al. (2010: 1166), Hsu et al. (2009: 256), Ortiz-Barrios et al.(2020: 14)
Information technology infrastructure	K10	Efficiency of information sharing throughout the supply chain	Prajapati et al. (2020: 306)
Location	K11	Installation place to minimize transportation costs	Ortiz-Barrios et al.(2020: 14)
Competitive power in price	K12	Competitive price	Kuo et al. (2010: 1166), Mafakheri et. al (2011: 54), Khan et. al (2018: 971)
Price	K13	Means logistics and payment	Zue et al. (2010: 309), Kuo (2010: 1166), Mafakheri et. al (2011: 54), Yücesan et. al (2019: 181) , Khan et. al (2018: 971)
Delivery time	K14	Delivery time	Zue at al. (2010: 309), Khan et. al (2018: 971)
Delivery method	K15	Shipping of products belongs to the buyer or seller.	Khan et. al (2018: 971)

This study consists of 7 parts. In the 2nd, 3rd and 4th parts, the methodology used for administration was introduced. In the 5th part, the administration was performed, and results were provided and discussed in the 6th part. In Chapter 7, the sensitivity of the results was analyzed using different methods.

Intuitionistic Fuzzy Set Teory

The fuzzy set elements introduced by Zadeh (1965: 338) are structures with membership degree. Classic (crisp) sets are defined as a collection of $x \in X$ elements or objects that can be finite, countable, or hyper-variable (Zimmermann, 2001: 342).

The term of fuzzy in the fuzzy set theory is expressed with triangular fuzzy numbers (TFN) of (l, m, u). While l and u show the lower and upper limit values of the fuzzy set, m refers to the single number of full membership. Mathematically expressed a triangle fuzzy number as follows.

$$\mu_{\tilde{A}}(X) = \begin{cases} \frac{x-l}{m-l} & l \leq x \leqslant m \\ \frac{u-x}{u-m} & m \leq x \leqslant u \\ 0 & Othes \end{cases}$$

(1)

The results of analytical operations with triangular fuzzy numbers are obtained by the following function (Shen et. al, 2013: 25):

$$For\ M_1 = (l_1, m_1, u_1)\ and\ M_2 = (l_2, m_2, u_2)$$

$$M_1 \oplus M_2 = l_1 + l_2, m_1 + m_2, u_1 + u_2$$

(2)

$$M_1 \ominus M_2 = l_1 - u_2, m_1 - m_2, u_1 - u_2$$

(3)

$$k \otimes M_1 = \begin{pmatrix} kl_1, km_1, ku_1 & k > 0 \\ ku_1, km_1, kl_1 & k < 0 \end{pmatrix}$$

(4)

$$M_1 \otimes M_2 = l_1 l_2, m_1 m_2, u_1 u_2\ if\ l_1\ and\ l_2 \geq 0$$

(5)

$$M_1 \oplus M_2 = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right) \quad if\ l_1\ and\ l_2 \geq 0$$

(6)

Fuzzy Analytic Hierarchy Process Method (F-AHP)

Analytic Hierarchy Process method suggested by Saaty (1980) is used frequently in the solution of complex decision problems. It is a qualitative weighting method used mostly in the weighting of criteria in the literature.

By the AHP method, a complex problem can be decomposed into sub-problems with hierarchical levels, where each level represents a set of criteria or properties according to each sub-problem (Sun, 2010: 7745).

In the AHP method, an evaluation is made for criteria and alternatives according to a 1-9 scale of Saaty. In the fuzzy AHP method, the comparisons made related to a subject are expressed with linguistic terms. The 1-9 scale equivalents of the linguistic terms are provided in Table 2. The superiority of the criteria over each other is determined by using the linguistic terms in this scale.

Table 2. TFN Equivalents of Linguistic Terms (Gümüş, 2009: 4071)

Fuzzy Numbers	Linguistic	Scale of fuzzy Numbers
9	Perfect	(8.9.10)
8	Absolute	(7.8.9)
7	Very good	(6.7.8)
6	Fairly good	(5.6.7)
5	Good	(4.5.6)
4	Preferable	(3.4.5)
3	Not bad	(2.3.4)
2	Weak advantage	1.2.3)
1	Equel	(1.1.1)

In the F-AHP method, Fuzzy extent analysis method, proposed by Chang (1996: 649), is used to obtain crisp weights from fuzzy comparison matrix.

$X = \{x_1, x_2, \ldots\ldots x_n\}$ while a set of objects and $U = \{u_1, u_2, \ldots\ldots u_n\}$ it can be a target set. Each object is taken and extent analysis is performed for each target respectively. The following expression expresses the scope analysis values performed for m goals for each object.

$M_{g,}^{1}, M_{g,}^{1}, \ldots\ldots\ldots\ldots M_{g,}^{m}$

$M_{gi}^{j} j = (1,2,3,4 \ldots\ldots n)$ triangular fuzzy numbers

The value of the fuzzy synthetic extent with respect to the i th object is defined as:

$$S = \sum_{j=1}^{m} M_{gi}^{j} \otimes [\sum_{i=1}^{n} M_{gi}^{j}]^{-1} \quad (7)$$

$$\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (8)$$

In the fuzzy evaluation matrix, after evaluating the criteria in the row according to the criteria in the column, the opposite of Eq. 8 is taken to evaluate the value in the column according to the value in the row.

$$[\sum_{i=1}^{n} M_{gi}^{j}]^{-1} = [1/\sum_{j=1}^{m} l_j, 1/\sum_{j=1}^{m} 1/_j, \sum_{j=1}^{m} u_j)]$$
(9)

The steps to calculate criterion weights with the F-AHP method are as follows (Ayyıldız and Gümüş, 2020: 36112; Kahraman et al., 2004: 176; Kulak and Kahraman, 2005: 199; Tolga et al., 2005: 94);

Step1. A comparison matrix is created for the criteria.

$$\tilde{A} = \begin{vmatrix} 1 & \tilde{a}_{12} & \cdots & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1/\tilde{a}_{1n} & & \cdots & \cdots & 1 \end{vmatrix} \qquad \tilde{a}_{ij=the\ pairwise\ comparison\ i\ and\ j}$$
(10)

$$\tilde{a}_{ij} = (a_{ij}^{1} \otimes a_{ij}^{2} \ldots \ldots \otimes a_{ij}^{n})$$
(11)

Step 2. Geometric means are calculated to describe the fuzzy weights of each criterion. (Hsieh et. Al, 2004: 577)

$$(\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \ldots \ldots \ldots \tilde{a}_{in})^{\frac{1}{n}}$$
(12)

$\tilde{r}_i$: *geometric mean of fuzzy comparison value of criterion i to each criterion,*

Step 3. Weights are determined for each criterion.

To obtain estimates of weight vectors under each criterion, we need to consider a principle of comparison for fuzzy numbers. We must determine the degree of probability that $x \epsilon R$ that is indefinitely constrained to belong to M is greater than an indefinitely constrained $y \epsilon R$ to belong to M (Chang, 1996: 651). Possibility of $M_1 = (l_1, m_1, u_1) and\ M_2 = (l_2, m_2, u_2)$ için $M_1 \geq M_2$,

$$V(M_1 \geq M_2) = \sup_{x > y} [\min(\mu_{M1}(x), \mu_{M1}(y)]$$
(13)

$$V(M_1 \geq M_2) = \begin{Bmatrix} 1 & m_2 > m_1 \\ 0 & l_2 > u_1 \\ \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} & otherwise \end{Bmatrix}$$

(14)

To compare $M1$ and $M2$'yi, both $V(M_1 \geq M_2)$, $V(M_2 \geq M_1)$ comparison values are needed. It can be done with the same method in other comparison.

It can be defined by the probability of the degree to which a convex fuzzy number is greater than k convex fuzzy numbers M_i $(i = 1,2,3, \dots \dots k)$.

$V(M \geq M_1, M_2, \dots \dots \dots \dots k) = V[(M \geq M_1)$ and $(M \geq M_2), \dots \dots \dots \dots M \geq M_k)$=min(V($M \geq M_i), i = 1,2, \dots \dots k$ (15)

$$d'(A_i) = minV(S_i \geq S_k) \quad (16)$$

k weight vectors are determined as follows.

$$w' = (d'(A_1), d'(A_2), \dots \dots \dots . d'(A_n))^T \quad (17)$$

The weights are normalized and the weight vector is obtained.

$$w = (d(A_1), d(A_2), \dots \dots \dots . d^d(A_n))^T \quad (18)$$

w *It is an non fuzzy number.*

The consistency of the weights obtained should be checked. For this, firstly, a random index (RIm) according to the mean value and another index (RIg) for the matrix of the geometric means of the lower and upper bounds were used (Table 3).

Table 3. Random İndex (Gögüs and Boucher, 1998: 137)

Matrix/Size	RI^m	RI^g
1	0	0
2	0	0
3	0.4889	0.1796
4	0.7937	0.2627
5	1.072	0.3597
6	1.1996	0.3818
7	1.2874	0.409
8	1.341	0.4164
9	1.3793	0.4348
10	1.4095	0.4455
11	1.4181	0.4536
12	1.4462	0.4776
13	1.4555	0.4691

14	1.4913	0.4804
15	1.4986	0.488

The ratio of the consistency index to the mean random index for the same ordered matrix is called the consistency ratio (CR).

$$CR = \frac{CI}{RI}$$
(19)

$$CI = \frac{\lambda - n}{n-1} \quad \lambda: average\ value, n: number\ of\ criteria$$
(20)

In the case of TFNs, consistency ratios must be calculated for both the mean value matrix and the matrix of geometric means of the lower and upper bounds.

Fuzzy WASPAS Method (F-WASPAS)

WASPAS method is one of the MCDM methods which was firstly suggested by Zvadskas et al. (2012). WASPAS integrating the weighted sum model (WSM) and weighted product model (WPM) has a higher accuracy degree regarding its results and overcomes complex multiplication calculation (Xiong et. Al., 2020: 6). WSM is the most widespread, easy and understandable method, and the points of an alternative are determined by calculating the weighted sum of its property values. However, the points of the WPM alternatives are determined as a product of each property's scale rating by a power equal to the attribute's significance weight. (Petrovic et al., 2019: 462).

Turskis et al. (2015: 879) identified the solution steps of the WASPAS method as follows:

Step 1. Decision Matrix is created

Table 4 is used for fuzzy equivalents of linguistic expressions in the decision matrix created by evaluating the alternatives according to the criteria.

$$\tilde{A} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{21} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{21} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} = \begin{bmatrix} (x^{l}_{11},, x^{m}_{11}, x^{u}_{11}) & (x^{l}_{12},, x^{m}_{12}, x^{u}_{12}) & \cdots & (x^{l}_{1n},, x^{m}_{1n}, x^{u}_{1n}) \\ (x^{l}_{21},, x^{m}_{21}, x^{u}_{21}) & (x^{l}_{22},, x^{m}_{22}, x^{u}_{22}) & & (x^{l}_{2n},, x^{m}_{2n}, x^{u}_{2n}) \\ \vdots & \vdots & & \\ (x^{l}_{m1},, x^{m}_{m1}, x^{u}_{m1}) & (x^{l}_{m2},, x^{m}_{m2}, x^{u}_{m2}) & \cdots & (x^{l}_{mn},, x^{m}_{mn}, x^{u}_{mn}) \end{bmatrix}$$
(21)

Table 4. Fuzzy Equivalence of Linguistic Expressions (Sadoughi, 2012: 2030).

Linguistic Variables	Fuzzy Equivalent
Very Poor (VP)	(0.0.1)
Poor (P)	(0.1.3)
Medium poor (MP)	(1.3.5)
Fair (F)	(3.5.7)
Medium Good (MG)	(5.7.9)
Good (G)	(7.9.10)
Very Good (VG)	(9.10.10)

Step 2. Decision matrix is obtained by normalizing
$\tilde{A}^N = [\tilde{x}_{ij}^N] \; (i = 1 \div m, j = 1 \div n)$

$$\tilde{x}_{ij}^N = \begin{cases} \frac{\tilde{x}_{ij}}{max x_i \tilde{x}_{ij}^u} \; C_j^+ - benefit \; critria \\ \frac{min x_i \tilde{x}_{ij}^l}{\tilde{x}_{ij}} \; C_j^- - cost \; critria \end{cases}$$
(22)

Step 3. Weighted decision matrix is determined for WSM $\tilde{A}_q$ve Weighted decision matrix is determined for WPM

Step 4. Optimality function values are calculated for WSM and WPM, respectively.

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{X}_{ij} \quad (23)$$

$$\tilde{P}_t = \prod_{t=1}^{n} \tilde{\tilde{X}}_{ij}$$
(24)

$i = 1 \; to \; n$

Here the center-of-area method was used as the simplest approach to apply for defuzzification:
$Q_i = \frac{1}{3}(Q_{i\alpha} + Q_{i\beta} + Q_{i\delta})$
(25)

$P_i = \frac{1}{3}(P_{i\alpha} + P_{i\beta} + P_{i\delta})$
(26)
Step 5. Integrated utility function values are calculated.

$K_i = \lambda \sum_{j=1}^{m} Q_i + (1 - \lambda) \sum_{j=1}^{m} P_i$
(27)

$$\lambda = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} Q_i + \sum_{i=1}^{m} P_i}$$

(28)

Step 6. The best alternative is chosen based on the maximum K_i values.

Case Study

Calculation of F-AHP Criteria Weights

Step 1. By using linguistic terms, the advantages of the criteria over each other were determined by 4 decision makers. Translation of linguistic terms on a scale of 1-9 (App1). Table 1 is used for the TFN equivalent of the comparison value of each decision maker.

Step 2. Geometric averages were taken and then the integrated comparison matrix was obtained using Table 2 as TFN (App2).

$$\tilde{a}_{45} = ((1,2,3)\otimes(1,1,1)\otimes(1,1,1)\otimes(1,2,3))^{1/4} = (1, 1.41, 1.73)$$

Step 3. Weights are determined (w_i).

$$\tilde{r}_1 = ((1 * 0.43 * 0.35 * 0.23 * \ldots \ldots 0.26)^{\frac{1}{15}}, (0.59 * 0.43 * 0.31 * \ldots \ldots 0.36)^{\frac{1}{15}}, \left(1 * 0.59 * 0.45 * \ldots \ldots 0.59)1^{\frac{1}{5}}\right) = (0.3189, 0.401, 0.5595)$$

Synthetic extents are determined by normalizing fuzzy weight values (App3)

$$\tilde{w}_1 = (0.3180, 0.4015, 0.5595) \otimes (0.0174, 0.0250, 0.0449) = (0.0139, 0.0223, 0.0422)$$

Probability comparison matrix is created (14,15) (App4). The mim values within the probability comparison matrix row values are obtained (16,17). With the normalization process, the sum of the weights of all criteria has been made equal to 1 (18) and criterion weights are calculated (App 5). The consistency of the obtained weights was calculated.

$$Consistency\ Ratio\ (CR_m) = 0{,}032$$

$$Consistency\ Ratio\ (g) = 0{,}0055$$

A consistency rate of 0.1 or less is considered acceptable for each matrix type (Saaty, 1980)

Alternative Selection with Fuzzy WASPAS

Step 1. Decision Matrix is Created (App5).

Step 2. Decision matrix is normalized. Computing the normalized matrix for Alternative 1 and Criterion 1:

$$(l,m,u)=\left(\frac{8{,}5}{10};\frac{9{,}75}{10};10/10\right)=(0{,}85;0{,}985;1)$$

Step 3. Weighted decision matrix $\tilde{A}_q$ for WSM and weighted decision matrix $\tilde{A}_p$ for WPM is calculated. Calculation of WSM weighted decision matrix for Alternative 1 and Criterion 1:

$$(l,m,u)=(0{,}0139*0{,}85;0{,}022*0{,}975;1*0{,}042)=(0{,}0118;0{,}0218;0{,}0422)$$

Calculation of WPM weighted decision matrix for Alternative 1 and Criterion 1:

$$(l,m,u)=(0{,}85^{0{,}042};0{,}975^{0{,}022};1^{0{,}0139}=(0{,}9932;0{,}9994;1)$$

Step 4. Optimality function values are calculated for WSM and WPM. Calculation of WSM optimality function values for Alternative 1:

$$Q_1=\frac{0{,}3179+0{,}6644+0{,}3268}{3}=0{,}7697$$

Calculation of WPM optimality function values for Alternative:

$$P_1=\frac{0{,}2206+0{,}5555+0{,}8163}{3}=0{,}5308$$

Step 5. Integrated utility function values are calculated.

$$\lambda=\frac{3{,}5439}{(3{,}5439+5{,}5535}=0{,}3895$$

$$K_1=(0{,}3895*0{,}7697)+(1-0{,}3895)*0{,}5308=0{,}6239$$

Step 6. Choosing the best alternative (Table 5).

Table 5. Ranking of the alternatives

Ki	0.623864	**0.675698**	0.524905	0.555751	0.656691	0.496546	0.470757	0.322515
Ranking	3	**1**	5	4	2	6	7	8

Sensitivity Analysis

In order to make the sensitivity analysis of selection results obtained by F-AHP and F-WASPAS methods, different methods of grading were used. The alternative 2 was selected to be the most proper one according to the grades of MARCOS, MABAC, SAW, ARAS, TOPSIS, EDAS methods. As can be understood by this conclusion, the hybrid F-AHP and F-WASPAS is an effective method regarding the solution of supplier selection problems.

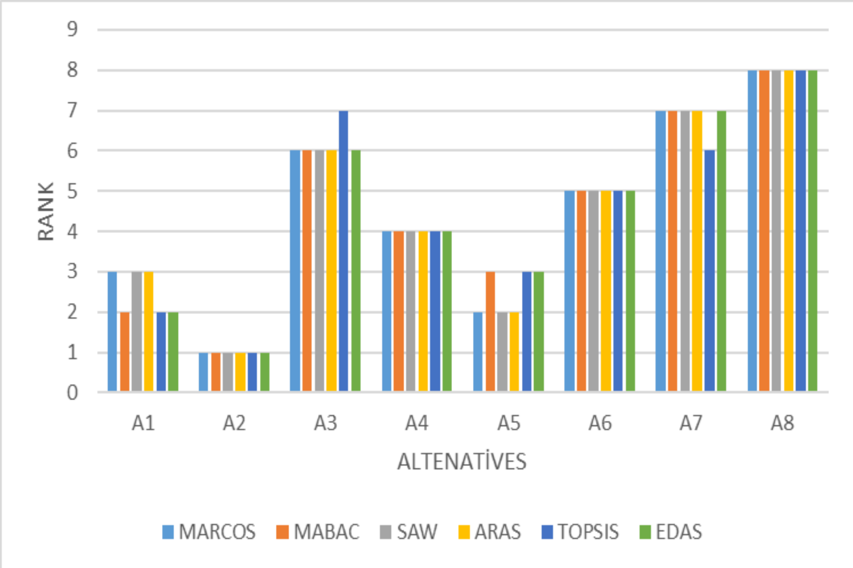

Fig 1. Sensitivity Analysis

Discussion and Conclusion

In this study, the solution of packaging supplier selection problem in a manufacturing company was subjected. 6 suppliers with which the company was working and 2 suppliers, planned to be worked with, in 2021 were evaluated. 15 criteria were used for the selection of the most proper supplier in sustainability respect. A group decision was taken to evaluate these criteria and alternatives. The reason behind group decision was to include different perspectives of production factor managers regarding supplier selection in the solution of the problem.

In general, the multi-criteria decision making is the most proper technique in supplier selection problems in which more than one alternatives are evaluated according to more than one criteria. The Hybrid Fuzzy AHP and WASPAS were suggested for the solution of the problem. The weights of the criteria, that is, their importance levels were determined by the Fuzzy AHP method. F-WASPAS method was utilised for the selection of the most proper supplier after alternatives were ranked. As a result of the evaluation, Alternative 2 was selected to be the most proper packaging supplier. In order to make the sensitivity analysis of selection results obtained by F-AHP and F-WASPAS methods, different methods of grading were used. The alternative 2 was selected to be the most proper one according to the grades of MARCOS, MABAC, SAW, ARAS, TOPSIS, EDAS methods. As can be understood by this conclusion, the hybrid F-AHP and F-WASPAS method is an effective method regarding the solution of supplier selection problems. It is considered that an objective and efficient model has been suggested as the criteria have been weighted by taking opinions of different experts and alternatives have been evaluated.

Appendix

App 1. Criteria evaluation table for DM1

DM1	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15
K1	1.00	0.50	0.33	0.25	0.33	0.25	0.25	0.25	0.33	0.33	0.33	0.25	0.25	0.25	0.33
K2	2.00	1.00	0.50	0.33	0.50	0.33	0.33	0.33	0.50	0.50	0.50	0.33	0.33	0.33	0.50
K3	3.00	2.00	1.00	0.50	1.00	0.50	0.50	0.50	1.00	1.00	1.00	0.50	0.50	0.50	1.00
K4	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K5	3.00	2.00	1.00	0.50	1.00	0.50	0.50	0.50	1.00	1.00	1.00	0.50	0.50	0.50	1.00
K6	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K7	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K8	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00	2.00
K9	3.00	2.00	1.00	0.50	1.00	0.50	0.50	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00
K10	3.00	2.00	1.00	0.50	1.00	0.50	0.50	0.50	1.00	1.00	1.00	0.50	0.50	0.50	1.00
K11	3.00	2.00	1.00	0.50	1.00	0.50	0.50	0.50	1.00	1.00	1.00	0.50	0.50	0.50	1.00
K12	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K13	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K14	4.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	2.00
K15	3.00	2.00	1.00	0.50	1.00	0.50	0.50	0.50	1.00	1.00	1.00	0.50	0.50	0.50	1.00

App 2. Comparison Table for criteria 1 (ISO 14001 certificate)

		Technical Capacity	
ISO 14001 certificate	0.2686	0.3689	0.5946
Cycle time	0.4387	0.5946	1.0000
Flexibility	0.7598	0.8409	1.0000
Technical Capacity	**1.0000**	**1.4142**	**1.7321**

Experience	1.0000	1.0000	1.0000
Relationship Level	1.0000	1.1892	1.3161
ISO 9001	1.1892	1.5651	1.8612
Refund or Waste Rate	1.0000	1.4142	1.7321
R&D capability	1.0000	1.1892	1.3161
Information technology infrastructure	1.0000	1.1892	1.3161
Location	1.0000	1.0000	1.0000
Competitive power in price	1.0000	1.6818	2.2795
Price	1.1892	2.2134	3.2237
Delivery time	1.1892	2.2134	3.2237
Delivery method	1.0000	1.0000	1.0000

App 3. Synthetic Extent

Criterias	**Fuzzy Sum of Each Row**			**Fuzzy Synthetic Extent**		
K1	4.7836	5.9643	8.4150	0.0139	0.0223	0.0422
K2	6.4205	8.7374	13.4873	0.0187	0.0327	0.0676
K3	10.7999	13.1649	16.6730	0.0314	0.0493	0.0835
K4	14.9888	18.5851	22.2643	0.0436	0.0696	0.1115
K5	11.7124	14.6559	18.8407	0.0341	0.0549	0.0944
K6	13.6134	17.8136	22.3109	0.0396	0.0667	0.1118
K7	16.8751	22.2937	27.4064	0.0491	0.0834	0.1373
K8	15.4540	20.2679	25.0152	0.0449	0.0759	0.1253
K9	13.4793	17.1931	21.9022	0.0392	0.0643	0.1097
K10	13.6618	17.3269	21.9022	0.0397	0.0648	0.1097
K11	11.6273	14.3278	18.0665	0.0338	0.0536	0.0905
K12	15.7547	21.9701	28.1628	0.0458	0.0822	0.1411
K13	19.2863	29.6472	39.4194	0.0561	0.1110	0.1975
K14	19.2863	30.2954	40.7819	0.0561	0.1134	0.2043
K15	11.8818	14.9467	19.2451	0.0346	0.0559	0.0964

Degree of Possibility of Mi > Mj

Criterias	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15

K1		0.693	0.285	0.000	0.199	0.054	0.000	0.000	0.065	0.054	0.210	0.000	0.000	0.000	0.18
K2	1.000		0.685	0.394	0.602	0.451	0.267	0.204	0.472	0.464	0.617	0.305	0.127	0.124	0.58
K3	1.000	1.000		0.663	0.898	0.716	0.502	0.350	0.746	0.737	0.919	0.533	0.307	0.299	0.88
K4	1.000	1.000	1.00		1.000	1.000	0.818	0.565	1.000	1.00	1.000	0.838	0.572	0.585	1.00
K5	1.000	1.000	1.000	0.775		0.822	0.613	0.428	0.853	0.845	1.000	0.639	0.405	0.395	0.98
K6	1.000	1.000	1.000	0.959	1.000		0.789	0.552	1.000	1.000	1.000	0.809	0.557	0.543	1.00
K7	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	0.746	0.730	1.00
K8	1.000	1.000	1.000	1.000	1.000	1.000	0.573		1.000	1.000	1.000	0.925	0.663	0.648	1.00
K9	1.000	1.000	1.000	0.927	1.000	0.967	0.470	0.849		0.992	1.000	0.781	0.535	0.522	1.00
K10	1.000	1.000	1.000	0.933	1.000	0.974	0.472	0.854	1.000		1.000	0.786	0.537	0.524	1.00
K11	1.000	1.000	1.000	0.746	0.978	0.796	0.344	0.672	0.827	0.819		0.609	0.375	0.365	0.96
K12	1.000	1.000	1.000	1.000	1.000	1.000	0.646	1.000	1.000	1.000	1.000		0.747	0.731	1.00
K13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		0.983	1.00
K14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		1.00
K15	1.0000	1.0000	1.0000	0.7950	1.0000	0.8412	0.3820	0.7210	0.8719	0.8642	1.0000	0.6581	0.4229	0.4124	

App4. Weights of criteria

Criterias	Degree of Possibility (Mi)	Normalization	Weights of Criteria	Rank
K1	0.0000	0.0000	0.0000	15
K2	0.1246	0.0166	0.0166	14
K3	0.2997	0.0398	0.0398	13
K4	0.5585	0.0742	0.0742	6
K5	0.3955	0.0526	0.0526	10
K6	0.5438	0.0723	0.0723	7
K7	0.7306	0.0971	0.0971	3
K8	0.5737	0.0762	0.0762	5

K9	0.4708	0.0626	0.0626	9
K10	0.4727	0.0628	0.0628	8
K11	0.3444	0.0458	0.0458	12
K12	0.6466	0.0859	0.0859	4
K13	0.9831	0.1306	0.1306	2
K14	1.0000	0.1329	0.1329	1
K15	0.3820	0.0508	0.0508	11

App5. Integrated Decision Matrix

Alternatifs/Criterias	W1			W2			W3			W4			W5		
	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1
	K1			K2			K3			K4			K5		
A1	8.5	9.8	10.0	7.0	9.0	10.0	2.5	4.5	6.5	9.0	10.0	10.0	9.0	10.0	10.0
A2	8.5	9.8	10.0	4.5	6.5	8.5	2.5	4.5	6.5	6.5	8.5	9.8	8.5	9.8	10.0
A3	6.5	8.5	9.8	4.5	6.5	8.5	6.0	8.0	9.5	4.5	6.5	8.5	6.5	8.5	9.8
A4	7.0	9.0	10.0	5.5	7.5	9.3	6.5	8.5	9.8	6.5	8.5	9.8	6.5	8.5	9.8
A5	8.0	9.3	9.8	3.0	5.0	7.0	5.5	7.5	9.0	7.0	9.0	10.0	7.5	9.3	10.0
A6	0.0	0.3	1.5	3.0	5.0	7.0	6.0	8.0	9.3	3.0	5.0	7.0	4.5	6.5	8.5
A7	0.0	0.3	1.5	1.0	3.0	5.0	6.0	8.0	9.3	3.0	5.0	7.0	3.0	5.0	7.0
A8	0.0	0.0	1.0	0.8	1.3	1.8	2.5	4.5	6.5	1.0	3.0	5.0	2.0	4.0	6.0

Alternatifs/Criterias	W6			W7			W8			W9			W10		
	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1
	K6			K7			K8			K9			K10		
A1	1.3	3.0	5.0	9.0	10.0	10.0	4.5	6.5	8.5	8.5	9.8	10.0	9.0	10.0	10.0
A2	1.3	3.0	5.0	9.0	10.0	10.0	4.0	6.0	8.0	8.5	9.8	10.0	7.0	9.0	10.0
A3	2.0	3.5	5.3	9.0	10.0	10.0	7.5	9.3	10.0	3.0	5.0	7.0	3.0	5.0	7.0
A4	2.5	3.8	5.3	7.5	9.3	10.0	5.0	7.0	9.0	3.0	5.0	7.0	3.0	5.0	7.0
A5	1.0	2.5	4.5	9.0	10.0	10.0	2.5	4.5	6.5	8.5	9.8	10.0	7.0	9.0	10.0
A6	1.8	3.0	4.8	7.0	9.0	10.0	3.0	5.0	7.0	3.0	5.0	7.0	3.0	5.0	7.0
A7	1.3	2.5	4.5	5.5	7.5	9.3	4.5	6.5	8.5	3.0	5.0	7.0	3.0	5.0	7.0
A8	2.3	3.3	4.8	0.0	0.0	1.0	4.0	6.0	7.8	0.0	0.0	1.0	0.0	0.0	1.0

Alternatifs/Criterias	W11			W12			W13			W14			W15		
	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.0	0.1	0.1
	K11			K12			K13			K14			K15		
A1	1.3	3.0	5.0	7.0	9.0	10.0	4.5	6.5	8.5	5.0	7.0	9.0	6.0	8.0	9.5
A2	0.3	1.5	3.5	4.5	6.5	8.5	3.0	5.0	7.0	3.0	5.0	7.0	6.0	8.0	9.5
A3	8.5	9.8	10.0	7.0	9.0	10.0	6.5	8.5	9.8	7.0	9.0	10.0	7.0	9.0	10.0
A4	7.5	9.3	10.0	5.0	7.0	9.0	4.5	6.5	8.5	5.0	7.0	9.0	6.0	8.0	9.5
A5	0.3	1.0	2.5	5.0	7.0	9.0	4.5	6.5	8.5	7.0	9.0	10.0	7.0	9.0	10.0
A6	6.0	7.8	9.3	3.0	5.0	7.0	3.0	5.0	7.0	5.0	7.0	9.0	5.5	7.5	9.3
A7	7.5	9.3	10.0	3.0	5.0	7.0	3.0	5.0	7.0	7.0	9.0	10.0	7.0	9.0	10.0
A8	5.5	7.5	9.3	3.0	5.0	7.0	2.5	4.5	6.5	3.0	5.0	7.0	6.0	8.0	9.5

References

Ahmet, F., Kılıç K., Modification to Fuzzy Extent Analysis Method and its performans Analysis, 6th IESM Congerance Seville, Spain, 2015.

Ayyildiz E., Gumus A.T., A novel spherical fuzzy AHP-integrated spherical WASPAS methodology for petrol station location selection problem: a real case study for İstanbul, Environmental Science and Pollution Research (2020) 27:36109–36120

Bellman RE, Zadeh LA. Decision-making in a fuzzy environment management. Science, 1970;17(4):141–64.

Chang, D-Y, Theory and Methodology, Applications of the extent analysis method on fuzzy AHP, European Journal of Operational Research (1996), 95; 649-655.

Gumus, A.-T., Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. Expert Systems with Applications, (2009), 36(2), 4067–4074

Gögüs, Ö., Boucher T. O., Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons, Fuzzy Sets and Systems (1998), 94; 133 144.

Hsieh, T.-Y., Lu, S.-T., & Tzeng, G.-H., Fuzzy MCDM approach for planning and design tenders selection in public office buildings. International Journal of Project Management, 2004, 22(7), 573–584.

Hsu C-W., Hu A.H., Applying hazardous substance management to supplier selection using analytic network process, Journal of Cleaner Production 2009, 17; 255–264

Jain N., Singh A. R., Upadhyay R. K., Sustainable supplier selection under attractive criteria through FIS and integrated fuzzy MCDM techniques, Internatıonal Journal Of Sustaınable Engıneerıng, DOI: 10.1080/19397038.2020.1737751.

Kahraman, C., Cebeci, U. ve Da Ruan, "Multi-Attribute Comparison of Catering Service Companies Using Fuzzy AHP: The Case of Turkey", International Journal of Production Economics, 2004, 87, 2, 171-184.

Kaushik V. , Kumar A , Gupta H., Dixit G., A hybrid decision model for supplier selection in Online Fashion Retail (OFR), International Journal of Logistics Research and Applications, International Journal of Logistics Research and Applications, 2020, 4-25.

Khan S. A., Kusi-Sarpong S., Arhin F. K., Kusi-Sarpong H., Supplier sustainability performance evaluation and selection: A framework and methodology, Journal of Cleaner Production 205 (2018) 964-979.

Kuo R.,. Wang Y, Tien F., Integration of artificial neural network and MADA methods for green supplier selection, Journal of Cleaner Production, 2010, 18, 1161-1170

Kulak, O. ve Kahraman, C., Fuzzy Multi-Attribute Selection Among Transportation Companies Using Axiomatic Design and Analytic Hierarchy Process, Information Sciences, 2005, 170, 2-4, 191-210.

Liou, J.-J.-H., Yen, L., & Tzeng, G.-H., Building an effective safety management system for airlines. Journal of Air Transport Management, 2008, 14(1); 20–26.

Ordoobadi S.M., Development of a supplier selection model using fuzzy logic, Supply Chain Management: An International Journal 2009, 14; 314–327.

Ortiz-Barrios M., Cabarcas-Reyes J., Ishizaka A., Barbati M., Jaramillo-Rueda N., Carrascal-Zambrano G. J., A hybrid fuzzy multi-criteria decision making model for selecting a sustainable supplier of forklift filters: a case study from the mining industry, Springer Science+Business Media, LLC, part of Springer Nature 2020.

Öztürk, B. A., Özçelik F., Sustainable Supplier Selection with A Fuzzy Multi-Criteria Decision Making Method Based on Triple Bottom Line, Business and Economics Research Journal, 2004, 5(3), 129-147.

Prajapati H., Kant R., Tripathi S. M., An integrated framework for prioritizing the outsourcing performance outcomes, Journal of Global Operations and Strategic Sourcing, DOI 10.1108/JGOSS-06-2019-00

Petrović G., Mihajlović J., Ćojbašić Z., MadićM., Marinković D., Comparıson Of Three Fuzzy Mcdm Methods For Solvıng The Supplıer Selectıon Problem, Facta Universitatis Series Mechanical Engineering, 2019, 17(3):455-469.

Saaty T. L., The analytic hierarchy process. New York, USA: McGraw-Hill, 1980

Shen, L., Olfat, L., Govindan, K., Khodaverdi, R., & Diabat, A., A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. Resources, Conservation and Recycling, 2013, 74: 170–179.

Sadoughi, S., Yarahmadi, R., Taghdisi, M. H., Mehrabi, M. (2012), Evaluating and prioritizing of performance indicators of health, safety, and environment using fuzzy TOPSIS, African Journal of Business Management, 6 (5), 2026-2033.

Singh R. K., Modgil S., Supplier selection using SWARA and WASPAS – a case study of Indian cement industry, Measurıng Busıness Excellence, 2020, 24(2), 243-265.

Sun C-C., A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods, Expert Systems with Applications 2010, 37: 7745–7754.

Sen D. P., Datta S., Mahapatra S.S., Sustainable supplier selection in intuitionistic fuzzy environment: a decision-making perspective, Benchmarking: An International Journal, 2018, 25(2), 545-557.

Szmıdt, E., Kacprzyk J., Using intuitionistic fuzzy sets m group decision making, Control and Cybernetics, 2002, 31(4), 1037-1053.

Stevic Z., , Pamucar D., Puska A., Chatterjee P., Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement Alternatives and Ranking according to Compromise Solution (MARCOS), Computers & Industrial Engineering, 2020, 140, (2019), 10623.

Tolga, E., Demircan, M. L. ve Kahraman, C., "Operating System Selection Using Fuzzy Replacement Analysis and Analytic Hierarchy Process", International Journal of Production Economic, 2005, 97, 1, 89-117

Turskis, Z.; Zavadskas, E. K.; Antucheviciene, J.; Kosareva, N., A hybrid model based on fuzzy AHP and fuzzyWASPAS for construction site selection, International Journal of Computers Communications & Control, 2015, 10(6), 113-128.

Tseng M.L., Chiu A.S., Evaluating firm's green supply chain management in linguistic preferences, Journal of Cleaner Production, 2013, 40; 22-31.

Zhu Q., Dou Y., Sarkis J., A portfolio-based analysis for green supplier management using the analytical network process, Supply Chain Management: An International Journal, 2010, 15; 306–319.

Xiong L., Zhong S., Liu S. , Zhang X., Li Y., An Approach for Resilient-Green Supplier Selection Based on WASPAS, BWM, and TOPSIS under Intuitionistic Fuzzy Sets, Hindawi Mathematical Problems in Engineering ,2020, 1-18, DOI: 10.1155/2020/1761893.

Wu, W.-W., & Lee, Y.-T., Developing global managers' competencies using the fuzzy DEMATEL method. Expert Systems with Applications, 2007; 32(2): 499–507.

Yucesan M , Mete S. , Serin F., Celik E., Gul M., An Integrated Best-Worst and Interval Type-2 Fuzzy TOPSIS Methodology for Green Supplier Selection, Mathematics 2019, 7, 182; 2-19.

Zimmermann, H. J., Fuzzy Set Theory-and Its Applications, Fourth Edition. New York: Springer Science+Business Media., 2001

Zadeh, Z.A.,, "Fuzzy sets", Information and Control, 1965, 2 (3): 338–353.

Zavadskas E. K., Turskis Z., Antucheviciene J., Zakarevicius A., Optimization of weighted aggregated sum product assessment, Elektron Elektrotech, 2012; 122, pp. 3–6, 2012.