Journal of Statistics & Management Systems
ISSN 0972-0510 (Print), ISSN 2169-0014 (Online)
Vol. 26 (2023), No. 6, pp. 1523–1536
DOI : 10.47974/JSMS-1186

Evaluation and selection of sustainable suppliers using fuzzy topsis method in a dairy product company

Reema Agarwal [§]
School of Basic and Applied Science
Shobhit Institute of Engineering and Technology
Meerut
Uttar Pradesh
India

Ankur Agrawal [†]
School of Business Studies
Sharda University
Greater Noida
Uttar Pradesh
India

Nitendra Kumar*
Department of Decision Sciences
Amity Business School
Amity University
Noida
Uttar Pradesh
India

Samrat Ray [‡]
The Institute of Industrial Management, Economics and Trade
Peter the Great Saint Petersburg Polytechnic University
Saint Petersburg
Russia

[§] *E-mail:* mrsreemaagarwal@gmail.com
[†] *E-mail:* ankur.aggrawal@sharda.ac.in
* *E-mail:* nkshukla.kumar4@gmail.com (Corresponding Author)
[‡] *E-mail:* samartray@rocketmail.com

Priyanka Agarwal [@]
Amity Business School
Amity University
Noida
Uttar Pradesh
India

Abstract

The selection of providers with sustainability considerations is the most significant activity in contemporary supply chain operations. Using the MCDM (Multi-Criteria Decision Making) technique, vendors are chosen. By choosing the right sustainable supplier, the organizations can upgrade their products, decrease costs, and satisfying customers' requirements. Dodla dairy is a renowned name in dairy companies in Hyderabad and Andhra Pradesh where purchasing managers choose the farmers. The purchasing managers gave their references so that the weights of the identified criterion and the ranking of another possibility on the basis of each criterion are to be determined. Quality and cost of the products are the most prominent criterion in the dairy supply chain. The method called Fuzzy TOPSIS is utilized in this paper to choose the dairy suppliers. The major goal of employing fuzzy logic is to assist purchasing managers in deciding how much importance to give each criterion and how to rank each sustainable dealer. The outcome of the Fuzzy TOPSIS technique, which has been successfully applied, establishes the weights of the criterion and the best and worst sustainable suppliers.

Subject Classification: *90C70, 97M40.*

Keywords: *Fuzzy logic, Fuzzy TOPSIS, Supplier selection, Dairy company.*

1. Introduction

Since 1998, India has been a prominent producer of dairy products in the world. Dairy activities are the major source of income and employment for the rural population in India. It is a backbone of the rural Indian economy as well. In the past, vendors sold fluid milk directly to the consumers or to companies, and all the dairy products were consumed domestically. India has a dairy market of INR 11,357 Billion at present and has a great potential to increase. That is why many national and international business organizations are showing interest in this area. These companies are focusing on high-value items including cheese, probiotic drinks, milkshakes, and yoghurt. Sustainable practices for the sustainable development of society are the core consideration of modern

[@] *E-mail:* **pagarwal5@amity.edu**

business organizations. Sustainable suppliers are the most important element in an organization's business operations.

MCDM is a strategy for dealing with decision-making processes that entail selecting the best option from a set of options. Sustainable supplier selection is also an MCDM problem as the decision has been based on multiple qualitative and quantitative criterions. Fuzzy -TOPSIS is an important technique used for supplier choice. This is a fuzzy idea that has been added to the traditional TOPSIS approach. The integrated technique helps build models for the selection of sustainable merchants and overcomes uncertainty by providing linguistic variables based on the inputs of the managers involved in procurement activities. A variety of economic, social, and environmental criteria are used in the selection of sustainable traders.

Literature Review

In the topic of supplier selection, there is a wealth of literature. Büyüközkan & Çifçi (2012) analyzed fuzzy MCDM approaches and integrated it with the fuzzy DEMATEL, ANP and TOPSIS for the process of selection of the best green supplier. Kannan et. al. (2013) solved the problem by using the techniques of F-AHP, F-TOPSIS, and MOLP. The integrated technique had been used for order allocation among suppliers.

Govindan et. al. (2013) measure the sustainability performance of different suppliers on the basis of triple bottom line technique in a fuzzy linked environment. Govindan et. al. (2014) in their research paper studied that the supply chain processes have great impact on sustainability. Kannan et. al. (2014) examined the process of assessment and choice of suppliers by using the technology of fuzzy TOPSIS for electronics organization. Stevic et. al. (2016) used TOPSIS embedded with Fuzzy AHP techniques for evaluation and selection of suppliers.

A brand-new kind of fuzzy theory was developed by Puska et. al. (2018) for use in group decision-making. Fuzzy TOPSIS and fuzzy AHP were used by Jain et. al. (2018) to identify and evaluate suppliers for the Indian auto industry. Wang et. al. (2018) investigated the sustainable supplier selection process in the manufacturing of edible oil for the SMEs food processing sector using a hybrid fuzzy analytical hierarchy technique and green data envelopment analysis. In the garment business, Wang et. al. (2019) looked at a fuzzy MCDM model for the assessment and selection of sustainable suppliers based on triple bottom line methodologies.

Matic et. al. (2019) developed a new integrated MCDM technique for the choice of a sustainable supplier in construction Companies. Zavadkas et. al. (2020) analyzed MCDM approaches to improve the process of sustainability engineering. Markovic et. al. (2020) studied an article concerning models integrated with subjective-objective MCDM for determining the alternative ranking of alternatives. For the selection of green suppliers, Gegovska et. al. (2020) applied Artificial Neural Networks (ANN) by using Fuzzy MCDM techniques. The fuzzy TOPSIS technique was used by Sahin et. al. (2020) for the Dry Bulk Carrier selection. Reema et. al. (2023) gives the mathematical model for selecting the green as well as sustainable supplier by implementing the F-ARAS techniques.

2. Fuzzy Topsis Technique

The TOPSIS method was invented in 1981 by Hwang and Yoon. The weights of the identified criterion and the ratings of the recognized alternatives are calculated using crisp numbers in the traditional TOPSIS technique. Crisp values, however, are frequently insufficient for real-world decision-making difficulties. Therefore, the fuzzy concept has been added with the conventional TOPSIS technique to address the linguistic variables, used to determine the weights of the identified criterion and the ratings of the suppliers. Since PIS (Positive - Ideal option) and NIS (Negative - Ideal Solution), conventional TOPSIS offers the best option. PIS and NIS are nothing more than the minimal and maximal geometrical separations between levels that are advantageous and those that are not. The fuzzy TOPSIS technique's key benefit is the incorporation of both helpful and harmful criteria.

Steps For Fuzzy-Topsis

Step (i) Identification of criterion, select suppliers and decision makers: Criteria which are identified are considered for the system. Then select suppliers whose rankings are determined. Then select decision makers who give their preferences to the suppliers according to the identified criterion.

Step (ii) Fuzzy Decision Matrix: Let's say '*k*' decision - makers will evaluate '*m*' suppliers as there are ''criteria. That can be translate in the form of the following matrix:

$$\begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \tag{1}$$

Step (iii) Combined – Fuzzy - Decision Matrix:It may be determined by:

$$x_{ij} = (u_{ij}, \quad v_{ij}, \quad w_{ij}) \tag{2}$$

Where $$u_{ij} = \min\{u_{ij}\} \tag{3}$$

$$v_{ij} = 1/k\{\Sigma v_{ij}\} \tag{4}$$

and $$w_{ij} = \max\{w_{ij}\} \tag{5}$$

Step (iv) Normalized- fuzzy decision matrix say $[N_{ij}]$: It is constructed on the following basis:

For beneficial criteria,

$$r_{ij} = \left(\frac{u_{ij}}{w_j^+}, \frac{v_{ij}}{w_j^+}, \frac{w_{ij}}{w_j^+}\right) \text{and } w_j^+ = \max\{w_{ij}\} \tag{6}$$

For non-beneficial criteria,

$$r_{ij} = \left(\frac{u_j^-}{w_{ij}}, \frac{u_j^-}{v_{ij}}, \frac{u_j^-}{u_{ij}}\right) \text{and } u_j^- = \min\{u_{ij}\} \tag{7}$$

Step (v) Weighted and normalized- Fuzzy Decision Matrix say $[V_{ij}]$: It can be represented as:

$$V_{ij} = N_{ij} * w_j \tag{8}$$

Where w_i represents criteria-weight.

Step (vi) Calculation of the F-PIS and F-NIS solutions: The FPIS, A^+ (fuzzy positive - ideal solution) and the FNIS, A^- (fuzzy negative - ideal solution) may be represented as:

$$A^+ = (N_1^+, N_2^+, \ldots, N_n^+) \tag{9}$$

$$A^- = (N_1^-, N_2^-, \ldots, N_n^-) \tag{10}$$

Where,

$$N_j^+ = \max\{N_{ij3}\} \tag{11}$$

And

$$N_j^- = \min\{N_{ij1}\} \tag{12}$$

Step (vii) Calculation of the distance of every alternative from the F-PIS and the F-NIS which may be calculated by:

$$d = \sqrt{\frac{1}{3}\{(u_1 - u_2)^2 + (v_1 - v_2)^2 + (w_1 - w_2)^2\}} \tag{13}$$

Then calculating d_i^+ and d_i^- where

$$d_i^+ = \Sigma d \tag{14}$$

$$d_i^- = \Sigma d \tag{14}$$

Step (viii) Calculating the closeness coefficient (CC_α):

$$CC_\alpha = d^- / (d^- + d^+) \tag{16}$$

Step (ix) Determining the ranking of the alternatives **-** If the value of closeness coefficient is maximum then the rank of alternative is one.

3. Application of fuzzy topsis technique in dairy company

In this part of the study, we will evaluate and select the sustainable supplier for the dairy product company, by applying fuzzy TOPSIS technique. Here, a total ten criteria for sustainable supplier selection have been identified and finalized. The criteria i.e. QC, DC, CC, EMC, GTC, SAC, FLC, EWC, FCC, RDC along with their references have been identified as shown in Table 1. The three purchasing managersgive their preferences to the six suppliers i.e. S1, S2, S3, S4, S5, S6 according to the identified criterion.

Table 1

Identification of criterion

S. No.	Identified Criterion	Explanations	References
1.	QC- Quality	Rankings for ISO quality certification are part of quality.	(FeyzioğLu et. al. 2010); Ho et al (2010)
2.	DC- Delivery	It includes delivery rates and on-time delivery.	(Yang et. al. 2007)
3.	CC-Cost	It includes the costs of materials, shipping, and customer service.	(Fallahpour et. al. 2015); Kannan et. al. 2015); (Humphreys et. al. 2006)
4.	EMC- Environment management system	It covers environmental environment friendly raw materials.	(Yang et. al. 2008); (Kannan et. al. 2015)
5.	GTC- Green technology	It includes packaging, raw materials, transportation, and environmental certification.	(Lee et. al. 2009); (Büyüközkan et. al. 2012); (Kannan et. al. 2015); Rostamzadeh et. al. 2015)
6.	SAC- Supportive activities for workers	It involves pay, professional advancement, and discrimination.	Govindan et. al. 2013);(Bai et. al. 2010)
7.	FLC- Flexibility	It includes flexibility in ordering and delivery time	(Kannan et. al. 2015); (FeyzioğLu et. al. 2010)
8.	EWC- Economic welfare and growth	It prioritizes the health and expansion of the economy.	(Bai and Sarkis 2010)
9.	FCC- Financial capability	Long-term business is encouraged by the solid financial capacity.	(Kannan et. al. 2015);
10.	RDC- Research and development	It has R & D capabilities.	(Lee et. al. 2009)

Fuzzy ratings of the entire identified criterion based on linguistic variables by all the purchasing managers and are shown in Table 2.

Table 2

Fuzzy ratings of the criterion based on Linguistic variables by the purchasing managers

Criteria	Linguistic variables	Fuzzy Ratings
QC	Very High	7,9,9
DC	High	5,7,9
CC	Average	3,5,7
EMC	High	5,7,9
GTC	Average	3,5,7
SAC	Very High	7,9,9
FLC	Average	3,5,7
EWC	High	5,7,9
FCC	High	5,7,9
RDC	Average	3,5,7

Firstly, constructing the fuzzy decision matrix of all the suppliers based on the identified criteria by using the linguistic variables in the form of triangular fuzzy numbers assessment by all the purchasing managers by using the equation (1). Then, constructing the combined fuzzy decision matrix assessment by all the three purchasing managers by using the equations (2), (3), (4) and (5) as shown in Table 3.

Table 3

Combined Fuzzy decision matrix assessment by all the purchasing managers

	QC	DC	CC	EMC	GTC	SAC	FLC	EWC	FCC	RDC
S1	5,8.3,9	5,7.6,9	3,5.6,9	1,5,9	1,7,9	1,5,9	1,5,9	1,5.6,9	3,7.6,9	3,6.3,9
S2	3,7,9	1,5.6,9	1,3,5	3,6.3,9	1,6.3,9	1,5,9	1,7,9	1,5.6,9	3,7.6,9	3,6.3,9
S3	1,3.6,7	3,5.6,9	3,7.6,9	5,7,9	3,6.3,9	1,3.6,7	1,6.3,9	1,5.6,9	3,6.3,9	3,7,9
S4	3,5.6,9	1,5,9	3,7,9	1,5,9	5,7.6,9	5,7.6,9	1,4.3,7	1,4.3,9	3,7,9	3,6.3,9
S5	5,8.3,9	5,7,9	1,4.3,9	3,6.3,9	1,4.3,9	1,5.6,9	3,7,9	5,8.3,9	1,3,5	3,6.3,9
S6	3,7,9	1,4.3,7	1,5.6,9	5,7,9	1,5,9	1,5,9	1,5.6,9	3,8.3,9	3,5.6,9	1,3,5

Now we are constructing the weighted normalized fuzzy decision matrix by using the equations (6), (7) and (8) and calculating the fuzzy positive ideal solution (FPIS, A^{+}) and the fuzzy negative ideal solution (FNIS, A^{-})by using the equations (9), (10), (11) and (12) as shown in Table 4.

Table 4

Weighted Normalized Fuzzy decision matrix

	QC	DC	CC	EMC	GTC	SAC	FLC	EWC	FCC	RDC
S1	3.8, 8.3, 9	2.7, 5.9, 9	0.3, 0.8, 2.3	0.5, 3.8, 9	0.3, 3.8, 7	0.7, 5, 9	0.3, 2.7, 7	0.5, 4.4, 9	1.6, 5.9, 9	1, 3.5, 7
S2	2.3, 7, 9	0.5, 4.4, 9	0.6, 1.6, 7	1.6, 4.9, 9	0.3, 3.5, 7	0.7, 5, 9	0.3, 3.8, 7	0.5, 4.4, 9	1.6, 5.9, 9	1, 3.5, 7
S3	0.7, 3.6, 7	1.6, 4.4, 9	0.3, 0.6, 2.3	2.7, 5.4, 9	1, 3.5, 7	0.7, 3.6, 7	0.3, 3.5, 7	0.5, 4.4, 9	1.6, 4.9, 9	1, 3.8, 7
S4	2.3, 5.6, 9	0.5, 3.8, 9	0.3, 0.7, 2.3	0.5, 3.8, 9	1.6, 4.2, 7	3.8, 7.6, 9	0.3, 2.4, 5.4	0.5, 3.3, 9	1.6, 5.4, 9	1, 3.5, 7
S5	3.8, 8.3, 9	2.7, 5.4, 9	0.33, 1.1, 7	1.6, 4.9, 9	0.3, 2.4, 7	0.7, 5.6, 9	0.3, 3.8, 7	2.7, 6.4, 9	0.5, 2.3, 5	0.3, 1.6, 3.8
S6	2.3, 7, 9	0.5, 3.3, 7	0.3, 0.8, 7	2.7, 5.4, 9	0.3, 2.7, 7	0.7, 5, 9	0.3, 3.1, 7	1.6, 6.4, 9	1.6, 6.4, 9	1, 1.6, 3.8
A^+	3.8, 8.3, 9	2.7, 5.9, 9	0.6, 1.6, 7	2.7, 5.4, 9	1.6, 4.2, 7	3.8, 7.6, 9	0.3, 3.8, 7	2.7, 6.4, 9	1.6, 6.4, 9	1, 3.8, 7
A^-	0.7, 3.6, 7	0.5, 3.3, 7	0.3, 0.7, 2.3	0.5, 3.8, 9	0.3, 2.4, 7	0.7, 3.6, 7	0.3, 2.4, 5.4	0.5, 3.3, 9	0.5, 2.3, 5	0.3, 1.6, 3.8

Now we are calculating the distance of each weighted alternative from the FPIS and the FNIS by using the equation (13) and are shown in the Tables 5 and 6.

Table 5

Distance between FPIS and each alternatives starting from FPIS

	QC	DC	CC	EMC	GTC	SAC	FLC	EWC	FCC	RDC
S1	0.0	0.0	2.2	1.5	0.7	2.3	0.6	1.7	0.3	0.2
S2	1.1	1.5	0.0	0.3	0.8	2.3	0.0	3.0	0.3	0.6
S3	3.4	1.1	2.7	0.0	0.5	3.1	0.2	1.7	0.9	0.2
S4	1.7	1.7	4.2	1.5	0.0	0.0	1.2	2.2	0.5	0.2
S5	0.0	0.2	0.3	0.7	1.3	2.1	0.0	0.0	3.3	0.2
S6	1.1	2.2	0.4	0.0	1.1	2.3	0.4	0.6	0.0	2.2

Table 6

Distance between FNIS and each alternatives starting from FNIS

	QC	DC	CC	EMC	GTC	SAC	FLC	EWC	FCC	RDC
S1	3.4	2.2	0.0	0.0	0.8	1.3	0.2	0.5	3.1	2.1
S2	2.4	1.2	2.7	0.8	0.6	1.3	1.0	0.5	3.1	2.1
S3	0.	1.4	0.0	1.5	0.7	0.0	1.1	0.5	2.8	2.2
S4	1.8	1.1	0.0	0.0	1.3	3.1	0.0	0.0	2.9	2.1
S5	3.4	2.1	2.7	0.6	0.0	1.6	1.2	2.2	0.0	3.6
S6	2.4	0.0	2.6	1.5	0.8	1.3	0.9	3.3	0.0	0.0

Now, finding d_i^+ and d_i^- by using the eq. (14) and eq. (15) and calculating the closeness coefficient (CC_α) by using the equation (16) and ranking of suppliers which is shown in the Table 7.

Table 7

Determining closeness coefficient and ranking of suppliers

Suppliers	d_i^+	d_i^-	**Closeness Coefficient**	**Ranking of Suppliers**
S1	10.42	14.20	0.57	3
S2	10.33	16.28	0.61	2
S3	14.11	10.86	0.43	6
S4	13.64	13.35	0.49	5
S5	8.39	17.68	0.67	1
S6	10.76	13.22	0.55	4

S5 > S2 > S1 > S6 > S4 > S3

It can be concluded that S5 is the top trader and S3 is the foulest trader, based on the ranking by applying the Fuzzy TOPSIS method for the company.

7. Conclusions, limitations and future scope of the study

In this study, the selection of sustainable suppliers in the context of triangular fuzzy numbers is examined using the fuzzy TOPSIS technique. To make an appropriate assessment of sustainable providers, this paper selects ten criteria, six suppliers, and three decision-makers. The criteria

are divided into advantageous and non- advantageous criteria where cost is the only non-advantageous criteria and all other criteria are beneficial. In the paper, six suppliers are selected and evaluated by ten criteria. Lastly, we examined and initiate that supplier 5 is the finest supplier and supplier 3 is the worst supplier.

Although it is currently not widely used, this research provides an adequate assessment outline for choosing sustainable suppliers and applies it to applied instances. The fuzzy TOPSIS method also has certain disadvantages. Using fuzzy TOPSIS will complicate data processing when there are many distinct suppliers and many different assessment criteria. In a subsequent study, we will enhance the fuzzy TOPSIS approach's application to make it more practical, understandable, and effective, as well as to make the conclusions more accurate. This will increase the framework's applicability. Future study in this area may make use of Pythagorean sets, reluctant fuzzy sets, and intuitionistic fuzzy sets. The goal of the research is to advance the solution.

References

[1] Büyüközkan, G. and Çifçi, G., A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Systems with Applications*, 39(3), pp. 3000-3011 (2012).

[2] Kannan, D., Khodaverdi, R., Olfat, L., Jafarian, A. and Diabat, A., Integrated fuzzy multi criteria decision making method and multiobjective programming approach for supplier selection and order allocation in a green supply chain. *Journal of Cleaner production*, 47, pp. 355-367 (2013).

[3] Govindan, K., Khodaverdi, R. and Jafarian, A., A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner production*, 47, pp. 345-354 (2013).

[4] Govindan, K., Azevedo, S.G., Carvalho, H. and Cruz-Machado, V., Impact of supply chain management practices on sustainability. *Journal of Cleaner production*, 85, pp. 212-225 (2014).

[5] Kannan, D., de Sousa Jabbour, A.B.L. and Jabbour, C.J.C., Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of Operational Research*, 233(2), pp. 432-447 (2014).

[6] Stević, Ž.,Tanackov, I., Vasiljević, M., Novarlić, B. and Stojić, G., An integrated fuzzy AHP and TOPSIS model for supplier evaluation. *Serbian Journal of Management*, 11(1), pp.15-27 (2016).

[7] Puška, L.a., Kozarević, S., Stević, Ž. and Stovrag, J., A New Way of Applying Interval Fuzzy Logic in Group Decision Making For Supplier Selection. *Economic Computation & Economic Cybernetics Studies & Research*, 52(2) (2018).

[8] Jain, V., Sangaiah, A.K., Sakhuja, S., Thoduka, N. and Aggarwal, R., Supplier selection using fuzzy AHP and TOPSIS: a case study in the Indian automotive industry. *Neural computing and applications*, 29(7), pp. 555-564 (2018).

[9] Wang, C.N., Nguyen, V.T., Thai, H.T.N., Tran, N.N. and Tran, T.L.A., Sustainable supplier selection process in edible oil production by a hybrid fuzzy analytical hierarchy process and green data envelopment analysis for the SMEs food processing industry. *Mathematics*, 6(12), p. 302 (2018).

[10] Wang, C.N., Yang, C.Y. and Cheng, H.C., A fuzzy multicriteria decision-making (MCDM) model for sustainable supplier evaluation and selection based on triple bottom line approaches in the garment industry. *Processes*, 7(7), p. 400 (2019).

[11] Matić, B., Jovanović, S., Das, D.K., Zavadskas, E.K., Stević, Ž.,Sremac, S. and Marinković, M., A new hybrid MCDM model: Sustainable supplier selection in a construction company. *Symmetry*, 11(3), p.353 (2019).

[12] Zavadskas, E.K., Pamučar, D., Stević, Ž. and Mardani, A., Multi-Criteria Decision-Making Techniques for Improvement Sustainability Engineering Processes. *Symmetry*, 12(6), p. 986 (2020).

[13] Marković, V., Stajić, L., Stević, Ž.,Mitrović, G., Novarlić, B. and Radojičić, Z., A novel integrated subjective-objective mcdm model for alternative ranking in order to achieve business excellence and sustainability. *Symmetry*, 12(1), p. 164 (2020).

[14] Gegovska, T., Koker, R. and Cakar, T., Green Supplier Selection Using Fuzzy Multiple-Criteria Decision-Making Methods and Artificial Neural Networks. *Computational Intelligence and Neuroscience*, (2020).

[15] Sahin, B., Yip, T.L., Tseng, P.H., Kabak, M. and Soylu, A., An application of a fuzzy TOPSIS multi-criteria decision analysis algorithm for dry bulk carrier selection. *Information*, 11(5), p. 251 (2020).

[16] Agarwal R, Nishad AK, Agarwal A, Husain S., Evaluation and Selection of a Green andSustainable Supplier by Using a Fuzzy ARAS Mathematical Modeling. New Mathematics andNatural Computation (2023), doi.org/10.1142/S1793005723500382.

[17] Agarwal, R., Agarwal, A., Kumar, N., Shah, A. M., Jawla, P. and Priya, S., Benchmarking the Interactions among Green and Sustainable Vendor Selection Attributes, *Ad. in Opera. Res.*, 8966856 (2022). https://doi.org/10.1155/2022/8966856.

[18] Feyzioglu, O. and Btiytikozkan, G., Evaluation of green suppliers considering decision criteria dependencies. In Multiple criteria decision making for sustainable energy and transportation systems, pp. 145-154, (2010). Springer, Berlin, Heidelberg.

[19] Ho, W., Xu, X. and Dey, P.K., Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of operational research*, 202(1), pp. 16-24 (2010).

[20] Yang, Y. and Wu, L., September. Grey entropy method for green supplier selection. In 2007 International conference on wireless communications, networking and mobile computing, pp. 4682-4685 (2007). IEEE.

[21] Fallahpour, A., Olugu, E.U., Musa, S.N., Khezrimotlagh, D. and Wong, K.Y., An integrated model for green supplier selection under fuzzy environment: application of data envelopment analysis and genetic programming approach. Neural Computing and Applications, 27(3), pp.707-725 (2016).

[22] Kannan, D., de Sousa Jabbour, A.B.L. and Jabbour, C.J.C., Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of operational research*, 233(2), pp. 432-447 (2014).

[23] Humphreys, P., McCloskey, A., Mclvor, R., Maguire, L. and Glackin, C., Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process. *International Journal of Production Research*, 77(12), pp. 2379-2419 (2006).

[24] Keshavarz Ghorabaee, M., Amiri, M., Zavadskas, E.K. and Antucheviciene, J., Supplier evaluation and selection in fuzzy environments: A review of MADM approaches. Economic research-Ekonomskaistrazivanja, 30(1), pp.1073-1118 (2017).

[25] Lee, A.H., Kang, H.Y., Hsu, C.F. and Hung, H.C., A green supplier selection model for high-tech industry. Expert systems with applications, 36(4), pp. 7917-7927 (2009).

[26] Biiyukdzkan, G. and (^ifgi, G., A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSfS to evaluate green suppliers. Expert Systems with Applications, 39(3), pp.3000-301E (2012).

[27] Rostamzadeh, R., Govindan, K., Esmaeili, A. and Sabaghi, M., Application of fuzzy VIKOR for evaluation of green supply chain management practices. Ecological Indicators, 49, pp. 188-203 (2015).

[28] Bai, C. and Sarkis, J., Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics*, 27(1), pp. 252-264 (2010).

Received May, 2023