

# SPHERICAL FUZZY SWARA-MARCOS APPROACH FOR GREEN SUPPLIER SELECTION

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## ABSTRACT

In a supply chain management, supplier selection is an important step to determine the structure of the model. Multi-criteria decision making methods are appropriate tools for dealing with the selection of suitable suppliers. In addition, fuzzy multi-criteria decision making approaches are helpful to include different and uncertain views of decision makers. In this study, a new combined fuzzy methodology is proposed to handle green supplier selection problem. The proposed model consists of a spherical fuzzy-SWARA method, which is used to calculate the criteria weights, and MARCOS method, which is applied to rank the alternatives. In the case study, green supplier selection problem of a textile company located in Turkey is discussed. Six alternative suppliers are evaluated against twelve green criteria, and alternatives are ranked. Finally, a sensitivity analysis is performed to compare the results of different scenarios.

## KEYWORDS

Green supplier selection, MARCOS, MCDM, Spherical fuzzy sets, Supply chain, Spherical fuzzy - SWARA.

# 1. INTRODUCTION

Supply chains are of great importance for businesses to maintain their main activities (Stevens, 1989). For the establishment and proper functioning of supply chains, the appropriate supplier must be selected. The criteria (attributes) to be considered when choosing a supplier often conflict with each other and cause difficulty in decision making (Akcan & Taş, 2019). Multi-criteria decision-making methods (MCDM) can be used to overcome these difficulties. These methods help to evaluate alternatives using criteria with different characteristics (De Boer *et al.*, 2001). In addition, it is appropriate to use fuzzy sets for imprecise statements of decision makers. These methods are frequently used in supplier selection practices (Yazdani *et al.*, 2017). In recent years, thanks to the increase in environmental awareness, sustainable supply chain has gained importance. Therefore, the concept of green supply chain that cares about the environment has emerged (Bali *et al.*, 2013). Sustainable criteria should be taken into account and determined as environmental performance evaluations. Using the MCDM methods, the suitable supplier in the green supply chain can be determined according to the sustainable criteria. Various MCDM have been used for green supplier selection in the literature, including some methods such as AHP (Mavi, 2015), PROMETHEE (Govindan *et al.*, 2017), TOPSIS (Cao *et al.*, 2015), ANP (Chung *et al.*, 2016), DEA (Dobos & Vörösmarty, 2019), VIKOR (Akman, 2015), ELECTRE (Kumar *et al.*, 2017), COPRAS (Liou, 2016), DEMATEL (Hsu, 2013), EDAS (He, 2019), TODIM (Sang & Liu, 2016), WASPAS (Ghorabae, 2016), MULTIMOORA (Sen *et al.*, 2017), and more. In this study, SWARA and MARCOS are combined with spherical fuzzy sets (SFS) for fuzzy MCDM problems.

SWARA method was introduced to the literature by Keršuliene *et al.* (2010). The method was applied to evaluate the criteria for the selection of agile supplier of an automobile manufacturer in Iran (Alimardan *et al.*, 2013), the evaluation of investments in high technology sectors (Hashemkhani & Bahrami, 2014), the design of bottle package (Stanujkic *et al.*, 2015), the selection of renewable energy technology (Ijadi Maghsoodi *et al.*, 2018), the appraisal of sustainable properties for renewable energy systems (Ghenai *et al.*, 2020).

After Zadeh (1965) introduce the ordinary fuzzy sets, numerous extensions have been proposed such as type-2 fuzzy sets (Zadeh, 1975), intuitionistic fuzzy sets (Atanassov,

1986), hesitant fuzzy sets (Torra, 2010), Pythagorean fuzzy sets (Yager, 2013), neutrosophic fuzzy sets (Smarandache, 1998), and so on. In the literature, many research combined SWARA and fuzzy sets. Some of these are those: ordinary fuzzy-SWARA (Perçin, 2019), hesitant fuzzy-SWARA (Kaya & Erginel, 2020), symmetric interval type-2 fuzzy-SWARA (Keshavarz-Ghorabae, 2018), neutrosophic fuzzy-SWARA (Rani & Mishra, 2020). In 2018, as an extension of fuzzy sets, spherical fuzzy numbers are introduced (Gündoğdu & Kahraman, 2019a). These fuzzy sets differ from others in that they are three-dimensional. “In spherical fuzzy numbers, while the squared sum of membership, non-membership and hesitancy parameters can be between 0 and 1, each of them can be defined between 0 and 1 independently to satisfy that their squared sum is at most equal to 1” (Gündoğdu & Kahraman, 2019b). Additionally, this study proposes a new spherical fuzzy-SWARA combination to the literature.

The Measurement of Alternatives and Ranking according to Compromise Solution (MARCOS) method is first introduced to the literature by Stević *et al.* (2020). Ilieva *et al.* (2020) used fuzzy MARCOS for ordering cloud storage service. Chattopadhyay *et al.* (2020) conducted a supplier selection study for the iron and steel industry using D-MARCOS. Stević and Brković (2020) used integrated FUCOM-MARCOS methodology to evaluate the human resources of the transportation company and to select the employee of the month. Stanković *et al.* (2020) studied on the risks of the main road with the fuzzy MARCOS. Badi and Pamucar (2020) used MARCOS with gray numbers in the supplier selection of Libyan Iron and Steel Company. Vesković *et al.* (2020) assessed possible solutions to problems of railway transportation in Republic of Srpska. F-MARCOS was chosen as one of the MCDM methods to compare the results. Mijajlović *et al.* (2020) employed FUCOM and fuzzy MARCOS to examine the competition of spa centers. Ulutaş *et al.* (2020) researched on the manual stacker selection for small warehouses, using CCSD, ITARA, and MARCOS. They used the MARCOS to evaluate the alternatives. Puška *et al.* (2020) performed MARCOS in selection of project management software.

In this study examines the green supplier selection problem of a textile firm. To examine environmental performance, twelve green criteria are determined. Seven decision makers (DM) working within the company evaluate the criteria and alternatives with the spherical fuzzy numbers. The weights of the criteria are calculated by the spherical fuzzy-SWARA

method. Applying the steps of the MARCOS, the alternatives are ranked. In the lights of the literature review, the original contribution of this study is that the proposed methodology is the pioneering work that combines spherical fuzzy-SWARA and MARCOS method. In addition, the proposed methodology is adapted to a real-life problem by investigating a green supplier selection case.

The rest of the paper is organized as follows. The preliminaries and definitions of the spherical fuzzy sets are given in Section 2. The proposed methodology involving the original combination of the spherical fuzzy-SWARA and MARCOS methods are also introduced in Section 2. Section 3 applies the proposed methodology on a green supplier selection case and a sensitivity analysis is applied for different weighting criteria scenarios. Finally, conclusion and future perspectives are discussed in Section 4.

## 2. METHODOLOGY

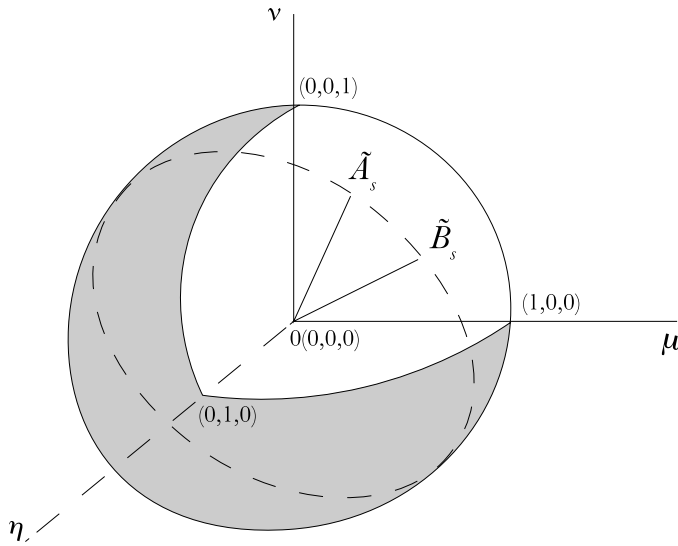
### 2.1. PRELIMINARIES

This section gives the preliminaries and definitions of the proposed method with spherical fuzzy information (Gündoğdu & Kahraman, 2019a; Gündoğdu & Kahraman, 2019b):

*Definition 1:* A spherical fuzzy set  $\tilde{A}$  of the universe of discourse  $X$  is given by:

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x), \eta_{\tilde{A}}(x), v_{\tilde{A}}(x)) | x \in X\} \quad (1)$$

The  $\mu_{\tilde{A}}(x)$ ,  $\eta_{\tilde{A}}(x)$  and  $v_{\tilde{A}}(x)$  represent membership degree, non-membership degree and hesitancy of  $x$  to  $\tilde{A}$ , respectively and they satisfy the condition  $\mu_{\tilde{A}}(x), \eta_{\tilde{A}}(x), v_{\tilde{A}}(x) \in [0, 1]$  ve  $0 \leq \mu_{\tilde{A}}(x)^2 + \eta_{\tilde{A}}(x)^2 + v_{\tilde{A}}(x)^2 \leq 1$ . The hesitancy parameter of  $\tilde{A}$  is expressed as  $\pi_{\tilde{A}}(x) = \sqrt{1 - \mu_{\tilde{A}}(x)^2 - \eta_{\tilde{A}}(x)^2 - v_{\tilde{A}}(x)^2}$ . The expression  $(\mu_{\tilde{A}}(x), \eta_{\tilde{A}}(x), v_{\tilde{A}}(x))$  is simply called the spherical fuzzy number (SFN), which can be represented as  $\alpha = (\mu, \eta, v)$ . In Figure 1, the spherical fuzzy set is illustrated.



**Figure 1.** Geometric representation of SFS.  
**Source:** (Gündoğdu & Kahraman, 2019b).

*Definition 2:* Let  $a_1 = (\mu_1, \eta_1, v_1)$  and  $a_2 = (\mu_2, \eta_2, v_2)$  be two SFN and let  $\lambda$  be a positive real number, then:

$$\alpha_1 \oplus \alpha_2 = \{ \sqrt{\mu_1^2 + \mu_2^2 - \mu_1^2 \mu_2^2}, \eta_1 \eta_2, \sqrt{(1 - \mu_2^2)v_1^2 + (1 - \mu_1^2)v_2^2 - v_1^2 v_2^2} \} \quad (2)$$

$$\alpha_1 \otimes \alpha_2 = \{ \mu_1 \mu_2, \sqrt{\eta_1^2 + \eta_2^2 - \eta_1^2 \eta_2^2}, \sqrt{(1 - \eta_2^2)v_1^2 + (1 - \eta_1^2)v_2^2 - v_1^2 v_2^2} \} \quad (3)$$

$$\lambda \alpha_1 = \{ \sqrt{1 - (1 - \mu_1^2)^\lambda}, \eta_1^\lambda, \sqrt{(1 - \mu_1^2)^\lambda + (1 - \mu_1^2 - v_1^2)^\lambda} \} \quad (4)$$

$$\alpha_1^\lambda = \{ \mu_1^\lambda, \sqrt{1 - (1 - \eta_1^2)^\lambda}, \sqrt{(1 - \eta_1^2)^\lambda + (1 - \eta_1^2 - v_1^2)^\lambda} \} \quad (5)$$

The complement of the spherical fuzzy number  $\alpha = (\mu, \eta, v)$  is defined as follows:

$$a^c = (v, \eta, \mu) \quad (6)$$

## 2.2. PROPOSED METHODOLOGY

In this section, the steps of combined the spherical fuzzy-SWARA and MARCOS methods are introduced. Firstly, the spherical fuzzy-SWARA method is given to calculate the weights of the criteria and then, MARCOS (Stević *et al.*, 2020) method is applied to rank of the alternatives. This study implements the spherical fuzzy sets to SWARA (Stanujkic *et al.*, 2015) steps as follows:

**Step 1.** Set the problem and select the experts/decision makers according to the problem.

**Step 2.** Ranking the criteria by the spherical fuzzy-SWARA. Criteria are ranked based on DM evaluations. The ranking is from highest importance to lowest.

*Step 2.1.* Determine  $\tilde{s}_j$  value:  $\tilde{s}_j$  is named “comparative importance of average value” by linguistic measures in Table 1.

**Table 1.** Linguistic measures of importance used for comparison.

Linguistic measures	( $\mu, \eta, \nu$ )
Equally Importance (EI)	(0.5, 0.4, 0.4)
Slightly Low Importance (SLI)	(0.4, 0.6, 0.3)
Low Importance (LI)	(0.3, 0.7, 0.2)
Very Low Importance (VLI)	(0.2, 0.8, 0.1)
Absolutely Low Importance (ALI)	(0.1, 0.9, 0.0)

**Source:** (Gündoğdu & Kahraman, 2019b).

*Step 2.2.* Determine  $\tilde{k}_j$  coefficient:  $\tilde{k}_j$  coefficient is calculated using Eq. (7):

$$\begin{cases} (0.5, 0.4, 0.4) & j = 1 \\ \tilde{s}_j + (0.5, 0.4, 0.4) & j > 1 \end{cases} \tag{7}$$

*Step 2.3.* Calculate the scores of  $\tilde{k}_j$  coefficient: the scores of the  $\tilde{k}_j$  is calculated with Eq. (8):

$$SI(\tilde{k}_j) = \sqrt{|100 * [(\mu_{\tilde{k}_j} - \nu_{\tilde{k}_j})^2 - (\eta_{\tilde{k}_j} - \nu_{\tilde{k}_j})^2]} \text{ for } \mu_{\tilde{k}_j} \geq \nu_{\tilde{k}_j} \tag{8}$$

*Step 2.4.* Determine  $q_j$  value: The importance vector value  $q_j$  is calculated with Eq. (9):

$$\begin{cases} 1 & j = 1 \\ \frac{x_{j-1}}{k_j} & j > 1 \end{cases} \tag{9}$$

*Step 2.5.* Determine  $w_j$  value:  $w_j$  values are the weights of the criteria, which is calculated using Eq. (10):

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \tag{10}$$

**Step 3.** Ranking the criteria by MARCOS (Stević *et al.*, 2020). Creating an initial decision matrix.

*Step 3.1.* Extend the initial decision matrix. Ideal (AI) and Anti-ideal (AAI) solutions are included to the matrix. Ideal (AI) solution is the best alternative. The below is the expression of ideal (AI) solution (Eq. 11):

$$AI = \max_i x_{ij} \text{ if } j \in B \text{ and } \min_i x_{ij} \text{ if } j \in C \tag{11}$$

Anti-ideal (AAI) solution is the worst alternative. The expression of anti-ideal (AAI) solution (Eq. 12) is as follows:

$$AAI = \min_i x_{ij} \text{ if } j \in B \text{ and } \max_i x_{ij} \text{ if } j \in C \tag{12}$$

Here, C symbolizes cost criteria to be minimized, whereas B symbolizes benefit criteria to be maximized. The extended decision matrix (X) is shown below:

$$X = \begin{matrix} AAI \\ A_1 \\ \dots \\ A_m \\ AI \end{matrix} \begin{bmatrix} x_{aa1} & \dots & x_{aan} \\ x_{11} & \dots & x_{1n} \\ \dots & \dots & \dots \\ x_{m1} & \dots & x_{mn} \\ x_{ai1} & \dots & x_{ain} \end{bmatrix}$$

Step 3.2. Normalize of matrix “X” with Eq. (13) and (14) for benefit criteria and cost criteria, respectively.  $x_{ij}$  and  $x_{ai}$  belong to matrix “X”.

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \tag{13}$$

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C \tag{14}$$

Step 3.3. Creating the weighted matrix “V” using Eq. (15).  $w_j$  values represent criteria weights which are calculated or determined.

$$v_{ij} = n_{ij} \times w_j \tag{15}$$

Step 3.4. Calculate the  $S_i$  and  $K_i$ .  $S_i$  stands for the sum of  $v_{ij}$  and  $K_i$  stands for the utility degree of alternatives. The values are calculated using Eq. (16), (17) and (18) below.

$$S_i = \sum_{j=1}^n v_{ij} \tag{16}$$

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{17}$$

$$K_i^- = \frac{S_i}{S_{aai}} \tag{18}$$



*Step 3.5.* Formulate the utility function.  $f(K_i^+)$  and  $f(K_i^-)$  are used for the utility function with respect to the ideal and anti-ideal solution, respectively. These values are calculated using Eq. (19), (20) and (21) below.

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{19}$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{20}$$

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \tag{21}$$

*Step 3.6.* Create the ranking of alternatives.

**Step 4.** Determining the best alternative which is the one with the highest score.

### 3. CASE STUDY

A textile manufacturer located in Marmara region in Turkey is selected as a case study of proposed model. The firm operates in the international market. Twelve sustainable criteria have been determined for the evaluation of six alternative suppliers, which supply raw materials. These green criteria are given in Table 2.

**Table 2.** The green criteria for textile manufacturer supplier selection.

Code	Criterion	Code	Criterion
C <sub>1</sub>	Environmental management system	C <sub>7</sub>	Resource/energy consumption
C <sub>2</sub>	Green packaging	C <sub>8</sub>	Green design
C <sub>3</sub>	Green transportation	C <sub>9</sub>	Green technology
C <sub>4</sub>	Green image	C <sub>10</sub>	Green purchasing
C <sub>5</sub>	Staff environmental management	C <sub>11</sub>	Pollution production
C <sub>6</sub>	Green warehousing	C <sub>12</sub>	Waste water

**Source:** own elaboration.

The criteria C<sub>7</sub>, C<sub>11</sub> and C<sub>12</sub> are cost type, the others are benefit type. The spherical fuzzy-SWARA steps are implemented based on the assessment of each of the seven DM from the company. The importance order of the criteria is given in Table 3. The results are combined by taking the arithmetic mean of the results for seven decision makers and the final criteria weights are calculated as in Table 4.

**Table 3.** The orders of importance.

Order	DM <sub>1</sub>	DM <sub>2</sub>	DM <sub>3</sub>	DM <sub>4</sub>	DM <sub>5</sub>	DM <sub>6</sub>	DM <sub>7</sub>
1	C <sub>4</sub>	C <sub>3</sub>	C <sub>1</sub>	C <sub>7</sub>	C <sub>7</sub>	C <sub>10</sub>	C <sub>1</sub>
2	C <sub>8</sub>	C <sub>6</sub>	C <sub>4</sub>	C <sub>4</sub>	C <sub>3</sub>	C <sub>2</sub>	C <sub>9</sub>
3	C <sub>1</sub>	C <sub>2</sub>	C <sub>5</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>3</sub>	C <sub>4</sub>
4	C <sub>6</sub>	C <sub>1</sub>	C <sub>7</sub>	C <sub>1</sub>	C <sub>9</sub>	C <sub>4</sub>	C <sub>3</sub>
5	C <sub>2</sub>	C <sub>4</sub>	C <sub>8</sub>	C <sub>2</sub>	C <sub>2</sub>	C <sub>1</sub>	C <sub>11</sub>
6	C <sub>9</sub>	C <sub>10</sub>	C <sub>10</sub>	C <sub>8</sub>	C <sub>1</sub>	C <sub>7</sub>	C <sub>8</sub>
7	C <sub>3</sub>	C <sub>7</sub>	C <sub>11</sub>	C <sub>10</sub>	C <sub>11</sub>	C <sub>9</sub>	C <sub>2</sub>
8	C <sub>5</sub>	C <sub>11</sub>	C <sub>2</sub>	C <sub>11</sub>	C <sub>5</sub>	C <sub>8</sub>	C <sub>6</sub>
9	C <sub>10</sub>	C <sub>12</sub>	C <sub>9</sub>	C <sub>12</sub>	C <sub>12</sub>	C <sub>12</sub>	C <sub>7</sub>
10	C <sub>11</sub>	C <sub>5</sub>	C <sub>3</sub>	C <sub>9</sub>	C <sub>8</sub>	C <sub>6</sub>	C <sub>5</sub>
11	C <sub>7</sub>	C <sub>8</sub>	C <sub>6</sub>	C <sub>6</sub>	C <sub>10</sub>	C <sub>11</sub>	C <sub>10</sub>
12	C <sub>12</sub>	C <sub>9</sub>	C <sub>12</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>5</sub>	C <sub>12</sub>

Source: own elaboration.

**Table 4.** The spherical fuzzy-SWARA results.

C <sub>n</sub>	DM <sub>1</sub>	DM <sub>2</sub>	DM <sub>3</sub>	DM <sub>4</sub>	DM <sub>5</sub>	DM <sub>6</sub>	DM <sub>7</sub>	Avg.	Ranking Results
C <sub>1</sub>	0,1072	0,1029	0,1575	0,0959	0,0853	0,0946	0,1572	0,1144	2
C <sub>2</sub>	0,0851	0,1132	0,0636	0,0872	0,0896	0,1095	0,0746	0,0890	4
C <sub>3</sub>	0,0736	0,1627	0,0551	0,1007	0,1087	0,1043	0,1081	0,1019	3
C <sub>4</sub>	0,1356	0,0936	0,1432	0,1158	0,1035	0,0993	0,1243	0,1165	1
C <sub>5</sub>	0,0701	0,0452	0,1061	0,0565	0,0739	0,0383	0,0398	0,0614	11
C <sub>6</sub>	0,1021	0,1302	0,0501	0,0621	0,0580	0,0543	0,0622	0,0741	9
C <sub>7</sub>	0,0528	0,0740	0,0964	0,1216	0,1141	0,0822	0,0518	0,0847	5
C <sub>8</sub>	0,1232	0,0430	0,0877	0,0793	0,0640	0,0746	0,0783	0,0786	7
C <sub>9</sub>	0,0810	0,0391	0,0578	0,0652	0,0941	0,0783	0,1429	0,0798	6
C <sub>10</sub>	0,0610	0,0851	0,0701	0,0755	0,0609	0,1533	0,0362	0,0774	8
C <sub>11</sub>	0,0581	0,0569	0,0668	0,0719	0,0776	0,0517	0,0901	0,0676	10
C <sub>12</sub>	0,0503	0,0542	0,0455	0,0685	0,0704	0,0597	0,0345	0,0547	12
Tot.	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	

Source: own elaboration.

In Step 3, MARCOS method is performed to evaluate the suppliers (A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>, A<sub>4</sub>, A<sub>5</sub>, A<sub>6</sub>) by using the criteria weights. The extended initial decision matrix “X” and normalized weighted matrix “V” are shown in Table 5 and Table 6.

**Table 5.** The extended initial decision matrix “X”.

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	C <sub>9</sub>	C <sub>10</sub>	C <sub>11</sub>	C <sub>12</sub>
<b>Weights</b>	0,1144	0,0890	0,1019	0,1165	0,0614	0,0741	0,0847	0,0786	0,0798	0,0774	0,0676	0,0547
<b>Type</b>	max	max	max	max	max	max	min	max	max	max	min	min

AAI	3,7143	3,1429	2,1429	2,1429	4,5714	4,0000	7,2857	4,0000	3,8571	1,8571	8,1429	6,8571
A <sub>1</sub>	3,8571	5,2857	3,0000	4,2857	7,5714	4,7143	3,2857	5,0000	3,8571	6,7143	6,7143	5,0000
A <sub>2</sub>	5,0000	5,2857	5,1429	4,0000	6,8571	4,4286	3,0000	5,0000	5,1429	7,0000	3,8571	6,1429
A <sub>3</sub>	5,4286	3,2857	5,0000	6,4286	5,0000	6,4286	7,2857	4,8571	8,4286	8,1429	8,1429	6,8571
A <sub>4</sub>	6,7143	5,8571	2,1429	6,1429	4,5714	5,4286	4,7143	6,1429	4,1429	1,8571	5,1429	5,2857
A <sub>5</sub>	3,7143	3,1429	5,0000	7,5714	7,7143	8,1429	7,0000	4,2857	5,0000	3,8571	3,5714	2,7143
A <sub>6</sub>	4,4286	4,1429	3,4286	2,1429	6,5714	4,0000	4,5714	4,0000	4,7143	5,0000	1,5714	4,5714
AI	6,7143	5,8571	5,1429	7,5714	7,7143	8,1429	3,0000	6,1429	8,4286	8,1429	1,5714	2,7143

Source: own elaboration.

In the Step 3.4 with the help of the values from Table 4,  $S_i$ ,  $K_i^+$  and  $K_i^-$  values are calculated by Equations (16), (17), and (18). In Step 3.5,  $f(K_i)$  values are found for utility functions and scores of alternatives are calculated by Equations (19), (20), and (21). The scores of the alternative suppliers (A<sub>1</sub>, A<sub>2</sub>, A<sub>3</sub>, A<sub>4</sub>, A<sub>5</sub>, A<sub>6</sub>) are shown in Figure 2. According to the results of MARCOS method, the best alternative of green supplier is A<sub>2</sub> with the highest score. Second one is A<sub>3</sub>, and third is A<sub>5</sub>.

Table 6. Normalized weighted matrix “V”.

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>	C <sub>6</sub>	C <sub>7</sub>	C <sub>8</sub>	C <sub>9</sub>	C <sub>10</sub>	C <sub>11</sub>	C <sub>12</sub>
AAI	0,0633	0,0477	0,0425	0,0330	0,0364	0,0364	0,0349	0,0512	0,0365	0,0177	0,0130	0,0217
A <sub>1</sub>	0,0657	0,0803	0,0594	0,0659	0,0603	0,0429	0,0773	0,0640	0,0365	0,0639	0,0158	0,0297
A <sub>2</sub>	0,0852	0,0803	0,1019	0,0615	0,0546	0,0403	0,0847	0,0640	0,0487	0,0666	0,0275	0,0242
A <sub>3</sub>	0,0925	0,0499	0,0991	0,0989	0,0398	0,0585	0,0349	0,0621	0,0798	0,0774	0,0130	0,0217
A <sub>4</sub>	0,1144	0,0890	0,0425	0,0945	0,0364	0,0494	0,0539	0,0786	0,0392	0,0177	0,0206	0,0281
A <sub>5</sub>	0,0633	0,0477	0,0991	0,1165	0,0614	0,0741	0,0363	0,0548	0,0473	0,0367	0,0297	0,0547
A <sub>6</sub>	0,0754	0,0629	0,0679	0,0330	0,0523	0,0364	0,0556	0,0512	0,0446	0,0476	0,0676	0,0325
AI	0,1144	0,0890	0,1019	0,1165	0,0614	0,0741	0,0847	0,0786	0,0798	0,0774	0,0676	0,0547

Source: own elaboration.

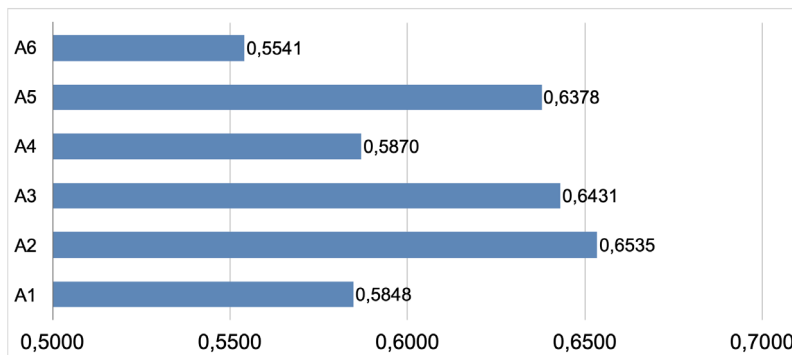
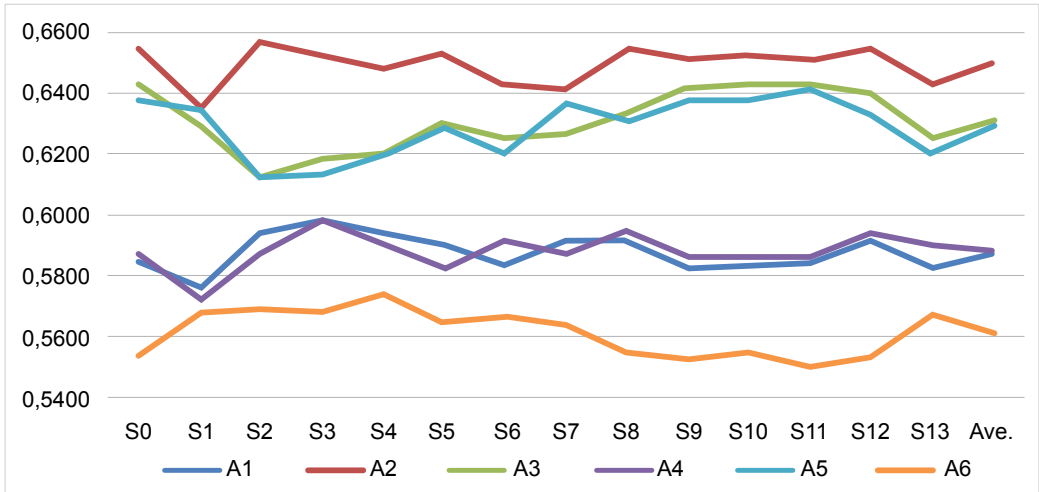


Figure 2. The ranking Scores of Alternatives.

Source: own elaboration.

To perform a sensitivity analysis of the proposed methodology, thirteen different scenarios are created by changing the weights of the criteria and the results are compared. According to the results,  $A_2$  is the first and  $A_6$  is the last in the ranking in all thirteen scenarios. Although ranking results changes in four scenarios, it is generally the same as the results of combined the spherical fuzzy-SWARA-MARCOS method.



**Figure 3.** Comparison of different scenarios.  
**Source:** own elaboration.

## 4. CONCLUSIONS

Nowadays, organizations are expected to be environmentally friendly in their supply chains. Therefore, selecting suitable green suppliers in sustainable supply chains is a very important task. In this study, the green supplier selection problem of a textile company is investigated. The spherical fuzzy-SWARA and MARCOS methods are handled in an integrated way. As a result of the combined spherical fuzzy-SWARA method, the highest weight criteria are green image, environmental management system and green transportation, respectively. According to the MARCOS method, the best green supplier is  $A_2$  and the ranking of alternatives is  $A_2 > A_3 > A_5 > A_4 > A_1 > A_6$ . Subsequently, for different scenarios, alternative suppliers are ranked, and the results are compared. Consequently, it is clear that the results of the proposed methodology is consistent. For future studies, the other fuzzy extensions of fuzzy sets can be considered in expressing the views of DMs, and new fuzzy MCDM methods should be implemented for sustainable supply chain problems.

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