SELECTION OF SUSTAINABLE SUPPLIERS IN AN AGRICULTURAL COMPANY USING THE MULTI-CRITERIA DECISION-MAKING METHOD

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Abstract

The decision on selecting a supplier in a business entity represents a great challenge for decision makers. The aim of this paper is to demonstrate the success of deciding on the most suitable supplier in an agricultural company by applying the fuzzy logic of multi-criteria decision-making methods which is based on predefined criteria that included a set of criteria related to supplier sustainability. The subject of research and analysis was a local agricultural company on the territory of the municipality of Bijeljina, which in its everyday business encounters the problem of choosing a supplier of various raw materials. The results of the conducted research showed that after the ranking of the five alternatives offered by the experts in the field, the first supplier is the closest to the ideal solution.

Key words: *multi-criteria decision making, fuzzy logic, TOPSIS method, suppliers*

Introduction

Modern business requires the adoption of timely rational decisions, whether they concern the production process itself or the procurement of the necessary funds for the production process. In this sense, the selection of suppliers of the necessary funds plays a decisive role in the entire business system or one company. The success of the organization is directly affected by the entire supply chain organization, which again largely depends on the correct choice of suppliers (Stević et al., 2019).

Also, Kannan et al., (2013) state that supplier selection is a vital component of any organization.

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When choosing an adequate supplier, an increasing influence is exerted on the preservation of the environment. This primarily arises as a result of the pressure of legal regulations, the buyer and the competitor (Matić et al., 2019). In this way, the "green" criteria are integrated into the final selection of suppliers. The choice of a sustainable supplier implies the introduction of new (green) components in its process (Maksimović et al., 2017). Thus, we get a kind of economic, social and environmental integration in the conventional supply chain.

Sustainability and sustainable development are explained as a combination of economic, social and environmental criteria related to the problem of supplier selection (Nourmohamadi Shalke et al., 2018). Sustainable supplier selection requires the determination of different sustainability objectives and criteria and methods for measuring sustainability. Although there is a large body of research on supplier selection, the literature on sustainable supplier selection is not extensive (Er Kara et al., 2016).

In the recent period, in many papers we find many examples of choosing a sustainable supplier using one of the multi-criteria methods. (Ghadimi and Heavey, 2014; Zhou and Xu, 2018; Hussain and Al-Aomar, 2018; Nourmohamadi Shalke, et al., 2018; Matić et al., 2019, Puška et al., 2021, etc.)

From this brief review of some papers, it can be seen that there are different methods, models and methodologies used to solve the problem of sustainable supplier selection. When developing methodologies and models, multicriteria decision-making tools (MCDM) are mostly used. In the MCDM method, a decision is made based on the evaluation of alternatives according to defined criteria (Puška et al., 2018). The decision is made based on the assessment of alternatives with defined criteria (Rozman et al., 2017), which can be qualitative and quantitative (Rozman et al., 2016). When quantitative criteria are used then classical MCDA methods are used, and if the criteria values are qualitative then fuzzy MCDA methods are used (Govindan et al., 2013; Stević et al., 2019, Nedeljković et al., 2021a; Nedeljković et al., 2021b).

The subject of research in this paper is the procurement of mineral fertilizers as a necessary raw material for the functioning of production in an agricultural company located in the city of Bijeljina. The aim of the paper would be to apply fuzzy logic on the example of agricultural production to make an adequate selection in terms of ambiguity in the answers of experts in the field.

Methodology

The source of data in the paper was the relevant literature from the analysed area as well as the answers of five experts from the subject area. Five suppliers / alternatives of mineral fertilizers were selected, and 13 criteria were used for the selection in the following order: *price, quality, delivery, technical capacity, innovation, supplier reputation, information sharing, impact on the local community, safety and health safety (health), pollution control, waste management, recycling and green product*.

The paper uses TOPSIS as a multicriteria method. According to Yavuz (2016), the TOPSIS method is one of the best techniques for selecting orders based on similarities with the ideal solution, and their application is satisfactory in all areas. Hwang and Yoon were the first to develop this method (1981). Chen (2000) extended this method using triangular fuzzy numbers that replace numerical language scales for grading and weighting.

Using this method, i.e. its fuzzy logic, we have predicted the following steps in this paper:

1. *Create a decision matrix*

2. *Create the normalized decision matrix*

Based on the positive and negative ideal solutions, a normalized decision matrix can be calculated by the following relation:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right); \; c_j^* = max_i \; c_{ij}; \text{ Positive ideal solution}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right); \; a_j^- = min_i \; a_{ij}; \text{ Negative ideal solution}$$

3. *Create the weighted normalized decision matrix*

Considering the different weights of each criterion, the weighted normalized decision matrix can be calculated by multiplying the weight of each criterion in the normalized fuzzy decision matrix, according to the following formula.

$$\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_{ij}$$

Where $\tilde{w}_{ij}$ represents weight of criterion c_j

4. *Determine the fuzzy positive ideal solution (FPIS, A*) and the fuzzy negative ideal solution (*$\boldsymbol{FNIS, A^-}$*)*

The FPIS and FNIS of the alternatives can be defined as follows:

$$A^* = \{\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*\} = \left\{\left(\max_j v_{ij} \,|\, i \in B\right), \left(\min_j v_{ij} \,|\, i \in C\right)\right\}$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\} = \left\{\left(\min_j v_{ij} \,|\, i \in B\right), \left(\max_j v_{ij} \,|\, i \in C\right)\right\}$$

Where $\tilde{v}_i^*$ is the max value of i for all the alternatives and $\tilde{v}_1^-$ is the min value of i for all the alternatives. *B* and *C* represent the positive and negative ideal solutions, respectively.

5. *Calculate the distance between each alternative and the fuzzy positive ideal solution* $\boldsymbol{A}^*$ *and the distance between each alternative and the fuzzy negative ideal solution* $\boldsymbol{A}^-$

The distance between each alternative and FPIS and the distance between each alternative and FNIS are respectively calculated as follows:

$$S_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) \qquad i=1,2,\ldots,m$$

$$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \qquad i=1,2,\ldots,m$$

d is the distance between two fuzzy numbers, when given two triangular fuzzy numbers (a_1, b_1, c_1) and (a_2, b_2, c_2), e distance between the two can be calculated as follows:

$$d_v(\tilde{M}_1, \tilde{M}_2) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$$

Note that $d(\tilde{v}_{ij}, \tilde{v}_j^*)$ and $d(\tilde{v}_{ij}, \tilde{v}_j^-)$ are crisp numbers.

6. *Calculate the closeness coefficient and rank the alternatives*

The closeness coefficient of each alternative can be calculated as follows*:*

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

Results of the research

In this study there are 13 criteria and 5 alternatives that are ranked based on FUZZY TOPSIS method. The table below shows the type of criterion and weight assigned to each criterion.

Table 1. Characteristics of Criteria

	Name	Type	Weight
1	Price	-	(0.077,0.077,0.077)
2	Quality	+	(0.077,0.077,0.077)
3	Delivery	+	(0.077,0.077,0.077)
4	Technical capacity	+	(0.077,0.077,0.077)
5	Innovation	+	(0.077,0.077,0.077)
6	Reputation	+	(0.077,0.077,0.077)
7	Sharing information	+	(0.077,0.077,0.077)
8	Impact on the local community	+	(0.077,0.077,0.077)
9	Safety and health	+	(0.077,0.077,0.077)
10	Pollution control	+	(0.077,0.077,0.077)
11	Waste management	+	(0.077,0.077,0.077)
12	Recycling	+	(0.077,0.077,0.077)
13	Green product	+	(0.077,0.077,0.077)

Source: Author's calculation

The following table shows the fuzzy scale used in the model.

Table 2. Fuzzy Scale

Code	Linguistic terms	L	M	U
1	Very low	1	1	3
2	Low	1	3	5
3	Medium	3	5	7
4	High	5	7	9
5	Very high	7	9	9

Source: According to Kiani Mavi et al., 2016; Mijajlović et al., 2020.

The best alternative is closest to the FPIS and farthest to the FNIS (Table 3 and Table 4) The closeness coefficient of each alternative and the ranking order of it are shown in the table below. (Table 5)

Table 3. The positive and negative ideal solutions

	Positive ideal	Negative ideal
Price	(0.036,0.039,0.052)	(0.041,0.052,0.077)
Quality	(0.053,0.070,0.077)	(0.036,0.053,0.067)
Delivery	(0.046,0.063,0.077)	(0.029,0.046,0.063)
Technical capacity	(0.047,0.066,0.077)	(0.032,0.051,0.069)
Innovation	(0.044,0.065,0.077)	(0.035,0.056,0.073)
Reputation	(0.038,0.057,0.077)	(0.026,0.045,0.065)
Sharing information	(0.033,0.055,0.077)	(0.029,0.046,0.068)
Impact on the local community	(0.037,0.059,0.077)	(0.015,0.037,0.059)
Safety and health	(0.037,0.059,0.077)	(0.015,0.037,0.059)
Pollution control	(0.033,0.055,0.077)	(0.015,0.037,0.059)
Waste management	(0.035,0.056,0.077)	(0.015,0.031,0.052)
Recycling	(0.035,0.056,0.077)	(0.015,0.031,0.052)
Green product	(0.033,0.055,0.077)	(0.015,0.037,0.059)

Source: Author's calculation

Table 4. Distance from positive and negative ideal solutions

	Distance from positive ideal	Distance from negative ideal
Supplier 1	0.08	0.133
Supplier 2	0.13	0.086
Supplier 3	0.144	0.074
Supplier 4	0.114	0.1
Supplier 5	0.081	0.133

Source: Author's calculation

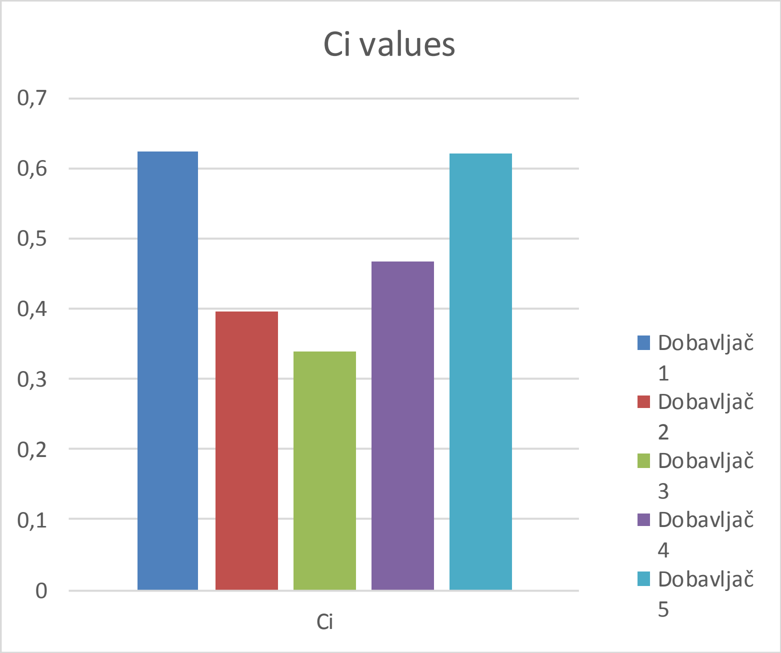
Table 5. Closeness coefficient

	Ci	rank
Supplier 1	0.623	1
Supplier 2	0.397	4
Supplier 3	0.338	5
Supplier 4	0.467	3
Supplier 5	0.621	2

Source: Author's calculation

The following graph shows the closeness coefficient of each alternative.

Figure 1. Closeness coefficient graph



Source: Author's calculation

Conclusion

According to the above, we can conclude the following:

The selection of suppliers is a complex process whose solution requires a rational approach and the use of modern methods of multi-criteria decision-making. Supplier sustainability is an important segment of his choice, especially when it comes to agricultural production and agribusiness. By setting the criteria that refer to it, the quality of the selected material is obtained.

In the case of qualitative value criteria, we should try to use the fuzzy logic of multi criteria decision-making, which gives us a more precise choice of the given alternatives.

According to the processed results by the multi-criteria TOPSIS method, i.e. its fuzzy logic, we conclude that supplier 1 is the most favourable for the selected agricultural company when it comes to the procurement of the raw materials in question. This is immediately followed by supplier 2 with slightly lower performance.

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