A Decision Support System for Multiple Criteria Alternative Ranking Using TOPSIS & VIKOR: A Case Study on Social Sustainability in Agriculture

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Abstract. TOPSIS and VIKOR are two well-known and widely-used multiple attribute decision making methods. Many researchers have compared the results obtained from both methods in various application domains. In this paper, we present the implementation of a web-based decision support system that incorporates TOPSIS and VIKOR and allows decision makers to compare the results obtained from both methods. Decision makers can easily upload the input data and get thorough illustrative results. Moreover, different techniques are available for each step of these methods. A real-world case study on social sustainability in agriculture is presented to highlight the key features of the implemented system. The aim of this study is to classify and rank the rural areas of Central Macedonia in Northern Greece using a set of eight social sustainability indicators.

Key words: multiple attribute decision making, TOPSIS, VIKOR, decision support system, sustainable agriculture

1 Introduction

Multi-Criteria Decision Making (MCDM) is a well-known branch of operations research that can be applied for complex decisions when a lot of criteria are involved. MCDM methods are separated into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM) [1]. The main distinction of these groups of methods is based on the determination of the alternatives. In MODM, the alternatives are not predetermined but instead a set of objective functions is optimized subject to a set of constraints. In MADM, the alternatives are predetermined and a limited number of alternatives is to be evaluated against a set of attributes. Well-known MODM methods include bounded objective function formulation, genetic algorithms, global criterion formulation and

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goal programming, while well-known MADM methods include AHP, ELECTRE, PROMETHEE, TOPSIS and VIKOR.

Various articles have compared different MADM methods. Zanakis et al. [2] compared the performance of eight MADM methods, namely ELECTRE, MEW, SAW, TOPSIS and four versions of AHP. They found out that the final rankings of the alternatives vary across methods, especially in problems with many alternatives. Opricovic and Tzeng [3] presented a comparative analysis of TOPSIS and VIKOR in order to show their similarities and differences. The analysis revealed that TOPSIS and VIKOR use different normalization techniques and that they introduce different aggregating functions for ranking. Opricovic and Tzeng [4] compared the extended VIKOR method with ELECTRE II, PROMETHEE and TOPSIS. Ranking results were similar for ELECTRE II, PROMETHEE and VIKOR. Chu et al. [5] presented a comparison of SAW, TOPSIS and VIKOR. They found out that TOPSIS and SAW had identical rankings, while VIKOR produced different rankings. They concluded that both TOPSIS and VIKOR are suitable for assessing similar problems and provide results close to reality.

The selection of the best MADM method for a specific problem is a difficult task. There are many factors that should be considered before selecting an MADM method or a combination of MADM methods. Guitouni & Martel [6] proposed a conceptual framework for articulating tentative guidelines to choose an appropriate MADM method. Recently, Roy & Słowiński [7] presented a general framework to guide decision makers in choosing the right method for a specific problem. Other methodologies have been also proposed for the selection of the best method in specific applications [8, 9, 10].

A common problem is that different MADM methods result to different ranking results. Hence, many researchers apply different MADM methods and compare the corresponding rankings. In this paper, we present the implementation of a web-based decision support system that incorporates TOPSIS and VIKOR and allows decision makers to compare the results obtained from both methods. Decision makers can easily upload the input data and get thorough illustrative results. Different techniques are available for each step of these methods and decision makers can select them to obtain rankings according to a case's needs. Finally, a real-world case study on social sustainability in agriculture is presented to highlight the key features of the implemented system. The aim of this study is to classify and rank the rural areas of Central Macedonia in Northern Greece using a set of eight social sustainability indicators.

The remainder of this paper is organized as follow. TOPSIS and VIKOR are reviewed in Section 2. In Section 3, the implemented decision support system is presented. Section 4 presents the real-world case study on social sustainability in agriculture that have been performed to highlight the key features of the implemented system. Finally, the conclusions of this paper are outlined in Section 5.

2 MADM Methods

Let us assume that an MADM problem has m alternatives, $A_1, A_2, \cdots, A_m$, and n decision criteria, $C_1, C_2, \cdots, C_n$. Each alternative is evaluated with respect to the n criteria. All the alternatives evaluations form a decision matrix $X = (x_{ij})_{m \times n}$. Let $W = (w_1, w_2, \cdots, w_n)$ be the vector of the criteria weights, where $\sum_{j=1}^{n} w_j = 1$.

This Section presents TOPSIS and VIKOR methods. Moreover, different techniques used in each step of these methods are discussed.

2.1 TOPSIS

TOPSIS (Technique of Order Preference Similarity to the Ideal Solution) method [11, 12] is one of the most classical and widely-used MADM methods. TOPSIS is based in finding ideal and anti-ideal solutions and comparing the distance of each one of the alternatives to those. It has been successfully applied in various application areas, like supply chain management, logistics, engineering and environmental management [13, 14, 15, 16, 17, 18].

TOPSIS method is comprised of the following five steps:

- **Step 1. Calculation of the weighted normalized decision matrix**: The first step is to normalize the decision matrix in order to eliminate the units of the criteria. The normalized decision matrix is computed using the vector normalization technique as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n$$

Another widely-used technique is the linear normalization technique. The normalized decision matrix is computed using the linear normalization technique as follows:

$$r_{ij} = \frac{x_{ij}}{x_j^+}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n, x_j^+ = max_i x_{ij}$$

for benefit criteria, and

$$r_{ij} = \frac{x_{ij}}{x_j^-}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n, x_j^- = min_i x_{ij}$$

for cost criteria. Several other normalization techniques can be incorporated at this step. Then, the normalized decision matrix is multiplied with the weight associated with each of the criteria. The normalized weighted decision matrix is calculated as follows:

$$v_{ij} = w_j r_{ij}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n$$

where w_j is the weight of the jth criterion.

- **Step 2. Determination of the ideal and anti-ideal solutions**: The ideal (A^+) and anti-ideal (A^-) solutions are computed as follows:

$$A^+ = \left(v_1^+, v_2^+, \cdots, v_n^+\right) = \left\{\left(max_j v_{ij} | j \in \Omega_b\right), \left(min_j v_{ij} | j \in \Omega_c\right)\right\}, j = 1, 2, \cdots, n$$

$$A^- = \left(v_1^-, v_2^-, \cdots, v_n^-\right) = \left\{\left(min_j v_{ij} | j \in \Omega_b\right), \left(max_j v_{ij} | j \in \Omega_c\right)\right\}, j = 1, 2, \cdots, n$$

where Ω_b is the set of the benefit criteria and Ω_c is the set of the cost criteria. Another technique is to use absolute ideal and anti-ideal points, that is:

$$A^+ = (1, 1, \cdots, 1), A^- = (0, 0, \cdots, 0)$$

- **Step 3. Calculation of the distance from the ideal and anti-ideal solutions**: The distance from the ideal and the anti-ideal solutions is computed for each alternative as follows:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, i = 1, 2, \cdots, m$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, i = 1, 2, \cdots, m$$

Apart from the Euclidean distance, the Manhattan distance

$$D_i^+ = \sum_{j=1}^{n} \left|v_{ij} - v_j^+\right|, i = 1, 2, \cdots, m$$

$$D_i^- = \sum_{j=1}^{n} \left|v_{ij} - v_j^-\right|, i = 1, 2, \cdots, m$$

and the Chebyshev distance

$$D_i^+ = max\left(\left|v_{ij} - v_j^+\right|\right), i = 1, 2, \cdots, m$$

$$D_i^- = max\left(\left|v_{ij} - v_j^-\right|\right), i = 1, 2, \cdots, m$$

can be used.

- **Step 4. Calculation of the relative closeness to the ideal solution**: The relative closeness of each alternative to the ideal solution is calculated as follows:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-}, i = 1, 2, \cdots, m$$

where $0 \leq C_i \leq 1$.

- **Step 5. Ranking the alternatives**: The alternatives are ranked from best (higher relative closeness value C_i) to worst.

2.2 VIKOR

VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method [3] is a widely-used MADM method. The method has been developed to provide compromise solutions to discrete multiple criteria optimization problems that include conflicting criteria that usually are expressed in different units. It has been successfully applied in various application areas, like supply chain management, logistics, engineering and environmental management [19, 20, 21, 22, 23, 24].

VIKOR method is comprised of the following five steps:

- **Step 1. Calculation of the aspired and tolerable levels**: The first step is to determine the best f_j^+ values (aspired levels) and the worst f_j^- values (tolerable levels) of all criterion functions, $j = 1, 2, \cdots, n$:

  $$f_j^+ = max_i f_{ij}, f_j^- = min_i f_{ij}, j = 1, 2, \cdots, n$$

  for benefit criteria, and

  $$f_j^+ = min_i f_{ij}, f_j^- = max_i f_{ij}, j = 1, 2, \cdots, n$$

  for cost criteria.
- **Step 2. Determination of the utility and the regret measures**: The utility measure S_i and the regret measure R_i are computed as follows:

  $$S_i = \sum_{j=1}^{n} w_j (f_j^+ - f_{ij})/(f_j^+ - f_j^-), i = 1, 2, \cdots, m$$

  $$R_i = max_j \left\{ w_j (f_j^+ - f_{ij})/(f_j^+ - f_j^-) \right\}, i = 1, 2, \cdots, m$$
- **Step 3. Calculation of the VIKOR index**: The VIKOR index is computed for each alternative as follows:

  $$Q_i = v \left(S_i - S^+\right) / \left(S^- - S^+\right) + (1-v) \left(R_i - R^+\right) / \left(R^- - R^+\right), i = 1, 2, \cdots, m$$

  where $S^+ = min_i S_i$, $S^- = max_i S_i$, $R^+ = min_i R_i$, $R^- = max_i R_i$; and v is the weight of the strategy of the maximum group utility (and is usually set to 0.5), whereas $1 - v$ is the weight of the individual regret.
- **Step 4. Ranking the alternatives**: The alternatives are ranked decreasingly by the values S_i, R_i and Q_i. The results are three ranking lists.
- **Step 5. Finding a compromise solution**: The alternative A^1, which is the best ranked by the measure Q (minimum), is proposed as a compromise solution if the following two conditions are satisfied:
  - **C1**. Acceptable advantage:

    $$Q\left(A^2\right) - Q\left(A^1\right) \geq DQ$$

    where A^2 is the second best ranked by the measure Q and $DQ = \frac{1}{m-1}$; m is the number of alternative solutions.

– **C2**. Acceptable stability in decision making: The alternative A^1 must also be the best ranked by the measures S or/and R. This compromise solution is stable within a decision making process, which could be one of the following strategies: (i) maximum group utility ($v > 0.5$), (ii) consensus ($v \approx 0.5$), or (iii) veto ($v < 0.5$).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

– Alternatives A^1 and A^2 if only condition $C2$ is not satisfied.
– Alternatives $A^1, A^2, \cdots, A^k$ if condition $C1$ is not satisfied; A^k is determined by the relation $Q\left(A^k\right) - Q\left(A^1\right) < DQ$ for maximum k (the positions of these alternative solutions are "in closeness").

These are the steps of the original version of the VIKOR method that is used in the implemented decision support system. The method was extended at a later stage with 4 new steps which provided a stability analysis to determine the weight stability intervals and included a trade-offs analysis [4, 25].

2.3 TOPSIS vs. VIKOR

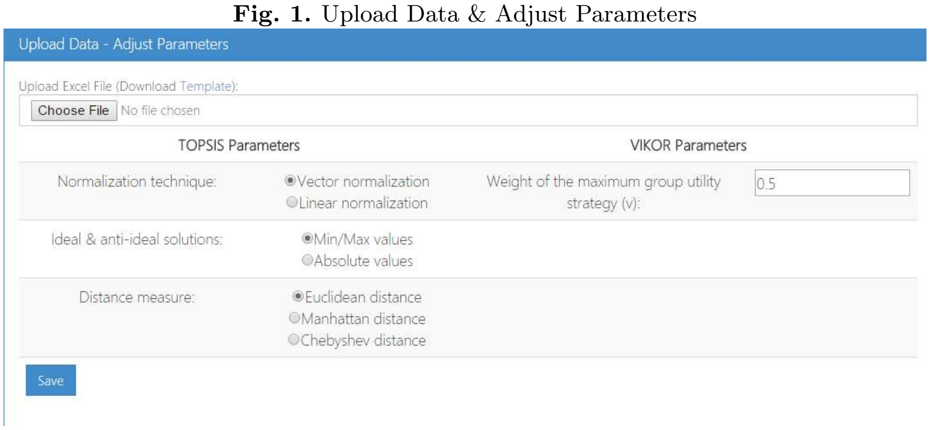
A brief description of the main differences of TOPSIS and VIKOR is presented in this section. A detailed comparison of TOPSIS and VIKOR can be found in the article by Opricovic & Tzeng [3]. The main differences of these methods are the following [3]:

– **Normalization**: Both methods use a normalization technique to eliminate the units of criterion functions. The difference appears in the normalization technique used by each method. TOPSIS uses vector normalization and the normalized values depend on the evaluation unit of a criterion. On the other hand, VIKOR uses linear normalization and the normalized values do not depend on the evaluation unit of a criterion. However, a later version of TOPSIS uses linear normalization. In the proposed DSS, we provide the opportunity for the decision maker to select different normalization techniques.
– **Aggregation**: TOPSIS introduces the ranking index, including distances from the ideal and the anti-ideal point. On the other hand, VIKOR utilizes an aggregating function that represents the distance from the ideal solution. VIKOR ranking index is an aggregation of the relative importance of all criteria and a balance between the total and individual importance. TOPSIS ranking index does not include the relative importance of the ideal and anti-ideal distances; they are simply summed.
– **Solution**: Both methods provide a ranking order. The highest ranked alternative by TOPSIS is the best in terms of ranking index, which does not mean that it is always the closest to the ideal solution. On the other hand, the highest ranked alternative by VIKOR is always the closest to the ideal solution. Moreover, VIKOR proposes a compromise solution with an advantage rate.

3 Implementation & Presentation of the Decision Support System

The web-based decision support system has been implemented using PHP, MySQL, Ajax and jQuery. Initially, the decision maker should upload the data of the case study and adjust methods' parameters (Figure 1). Decision makers can download an Excel template, incorporate their data and upload the Excel file to the decision support system. Moreover, they can select different parameters for each method. More specifically, decision makers can select the normalization technique (vector or linear), the technique to calculate the ideal and anti-ideal solutions (min/max or absolute values) and the distance measure to be used (Euclidean, Manhattan or Chebyshev) for TOPSIS method and the weight of the maximum group utility strategy (v) for VIKOR method. The results are graphically and numerically displayed, allowing the decision makers to easily compare the rankings obtained by the two methods (Figure 2). The DSS can also output a thorough report in a pdf file containing the results of TOPSIS and VIKOR. The result of TOPSIS is the ranking index, while the result of VIKOR is a compromise solution (if the acceptable advantage condition (C1) and the acceptable stability condition (C2) are met) or a set of compromise solutions.

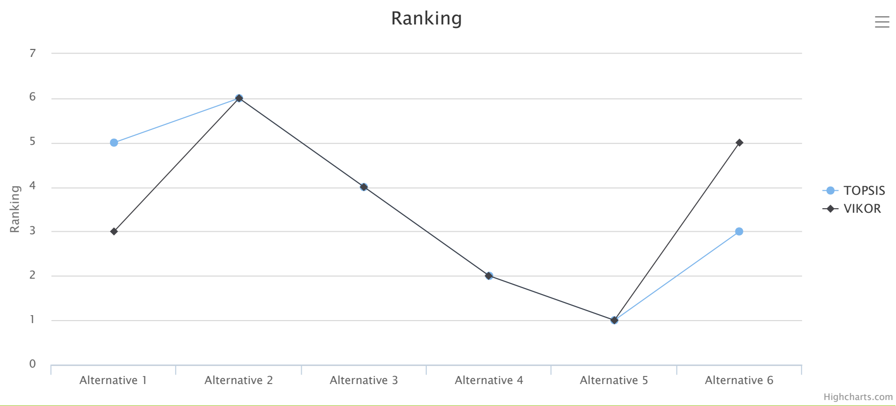
Fig. 1. Upload Data & Adjust Parameters



4 Case Study

The aim of this case study is to classify and rank the rural areas of Central Macedonia in Northern Greece using a set of eight social sustainability indicators. In order to measure these indicators, a survey was conducted in farm households of the Region of Central Macedonia in Northern Greece. The sample of the survey was 145 farm households from the seven prefectures of the region (Chalkidiki,

Fig. 2. Results & Ranking



		Alternatives						Ranking
		Alternative 1 (A1)	Alternative 2 (A2)	Alternative 3 (A3)	Alternative 4 (A4)	Alternative 5 (A5)	Alternative 6 (A6)	
TOPSIS	D^+	0.1411	0.1711	0.1284	0.0859	0.0300	0.1191	A5, A4, A6, A3, A1, A2
	D^-	0.0891	0.0832	0.0818	0.1382	0.2008	0.1158	A5, A4, A6, A1, A2, A3
	C	0.3870	0.3271	0.3892	0.6167	0.8700	0.4928	A5, A4, A6, A3, A1, A2
VIKOR	S	0.6290	0.7670	0.6010	0.3100	0.0800	0.5160	A5, A4, A6, A3, A1, A2
	R	0.2000	0.4000	0.2667	0.1333	0.0800	0.3333	A5, A4, A1, A3, A6, A2
	Q	0.5871	1.0000	0.6709	0.2507	0.000	0.7131	A5, A4, A1, A3, A6, A2

Imathia, Kilkis, Pella, Pieria, Serres, Thessaloniki) who have subsidized with direct payments from the first pillar of the Common Agricultural Policy. The aim of the survey was to measure the social sustainability of the farm households in European Union rural areas. The survey included a detailed questionnaire with personal and phone interviews. A large number of social and economic indicators was measured. From this set of indicators, we have selected 8 indicators that can represent the main social characteristics of the farm households. The selected indicators are the following:

1. **Highest education level attained by one household's member**: According to OECD [26]: "Education plays a key role in providing individuals with the knowledge, skills and competences needed to participate effectively in society and in the economy". Hence, this is a benefit criterion (the highest education level of at least one member of the farm household would increase the farmer's knowledge and skills). The scale used for this criterion is the following: 1 - elementary, 2 - primary, 3 - high school, 4 - bachelor, 5 - master, and 6 - PhD.

2. **Number of employed in the farm household**: According to Eurostat Labour Force Survey (LFS) [27]: an employed person is "a person aged 15 and over who during the reference week performed work - even if just for one hour a week - for pay, profit or family gain". This is a benefit criterion.
3. **Number of long-term unemployed in the farm household**: According to OECD [26]: "Long-term unemployment is defined as referring to people who have been unemployed for 12 months or more". This is a cost criterion.
4. **Percentage of the total household gross revenue comes from farming**: The gross revenue comes from farming refers to monetary and non-monetary income received by farm operators. This is a benefit criterion (the maximization of the gross revenue comes from farming would support professional farmers). The scale used for this criterion is the following: 1 - less than 10%, 2 - $10-29\%$, 3 - $30-49\%$, 4 - $50-69\%$, 5 - $70-89\%$, 6 - more than 89%.
5. **Employment rate percentage in the farm household**: According to OECD [26]: "Employment rate is defined as the proportion of working age adults employed with working age between 15 and 64 years old". This is a benefit criterion.
6. **Share of labour used in off farm activities**: This criterion refers to the portion of the farm household income obtained by nonfarm wages and salaries, pensions, and interest income earned by farm families. This is a cost criterion (the minimization of the labour's share in off farm activities would support professional farmers).
7. **Share of the farm income comes from subsidies**: Farm subsidy is a governmental subsidy paid to farmers to support their income. This is a cost criterion (the minimization of the farm income comes from subsidies would support professional farmers).
8. **Number of household's members that have a formal agricultural education**: This is a benefit criterion (the formal agricultural education of at least one member of the farm household would increase the farmer's knowledge and skills).

Table 1 presents the average indicators of the data collected for each prefecture. TOPSIS method was performed using the vector normalization and the finding of the best and worst performance for the ideal and anti-ideal solutions, while VIKOR method was performed setting the weight of the strategy of the maximum group utility v equal to 0.5. The criteria are equally important ($w_j = 0.125, j = 1, 2, \cdots, n$). Table 2 and Figure 3 present the rankings obtained from each method. TOPSIS ranks the prefecture of Kilkis as the best and the prefecture of Pieria as the worst rural area of Northern Greece, while VIKOR ranks the prefecture of Pella as the best and the prefecture of Chalkidiki as the worst rural area of Northern Greece. The rankings are not similar as TOPSIS and VIKOR use different kinds of normalization to eliminate the units of criterion functions and different aggregating functions for ranking [3].

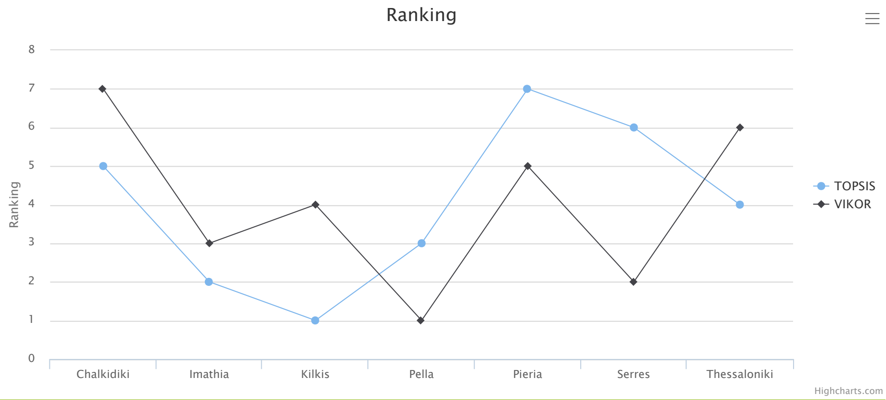
Table 1. The Decision Matrix

Prefecture	Highest education level attained by one household's member	Number of employed in the farm household	Number of long-term unemployed in the farm household	Percentage of the total household gross revenue comes from farming	Employment rate percentage in the farm household	Share of labour used in off farm activities	Share of the farm income comes from subsidies	Number of household's members that have a formal agricultural education
Chalkidiki	3.70	3.30	0.35	4.95	0.50	0.03	0.48	0.30
Imathia	3.25	2.95	0.00	5.40	0.72	0.03	0.45	0.30
Kilkis	3.65	2.94	0.12	5.12	0.62	0.02	0.44	0.53
Pella	3.75	3.63	0.19	5.19	0.55	0.00	0.44	0.38
Pieria	4.19	4.06	0.50	5.19	0.50	0.15	0.43	0.44
Serres	3.71	3.18	0.24	5.06	0.55	0.07	0.46	0.26
Thessaloniki	3.55	3.14	0.00	5.09	0.59	0.01	0.53	0.18

Table 2. Results & Ranking

		Alternatives							Ranking
		Chalkidiki (A1)	**Imathia (A2)**	**Kilkis (A3)**	**Pella (A4)**	**Pieria (A5)**	**Serres (A6)**	**Thessaloniki (A7)**	
	D^+	0.0767	0.0423	0.0328	0.0429	0.1430	0.0786	0.0517	A3, A2, A4, A7, A1, A6, A5
TOPSIS	D^-	0.0929	0.1278	0.1263	0.1261	0.0407	0.0760	0.1363	A7, A2, A3, A4, A1, A6, A5
	C	0.5476	0.7514	0.7938	0.7461	0.2217	0.4919	0.7250	A3, A2, A4, A7, A1, A6, A5
	S	0.6570	0.3810	0.3910	0.3750	0.4650	0.6050	0.6060	A4, A2, A3, A5, A6, A7, A1
VIKOR	R	0.1250	0.1250	0.1250	0.0966	0.1250	0.0982	0.1250	A4, A6, A1 $\approx$ A2 $\approx$ A3 $\approx$ A5 $\approx$ A7
	Q	1.0000	0.5106	0.5284	0.0000	0.6596	0.4360	0.9096	A4, A6, A2, A3, A5, A7, A1

Fig. 3. Results & Ranking



		Alternatives							Ranking
		Chalkidiki (A1)	Imathia (A2)	Kilkis (A3)	Pella (A4)	Pieria (A5)	Serres (A6)	Thessaloniki (A7)	
TOPSIS	D^+	0.0767	0.0423	0.0328	0.0429	0.1430	0.0786	0.0517	A3, A2, A4, A7, A1, A6, A5
	D^-	0.0929	0.1278	0.1263	0.1261	0.0407	0.0760	0.1363	A7, A2, A3, A4, A1, A6, A5
	C	0.5476	0.7514	0.7938	0.7461	0.2217	0.4919	0.7250	A3, A2, A4, A7, A1, A6, A5
VIKOR	S	0.6570	0.3810	0.3910	0.3750	0.4650	0.6050	0.6060	A4, A2, A3, A5, A6, A7, A1
	R	0.1250	0.1250	0.1250	0.0966	0.1250	0.0982	0.1250	A4, A6, A1 ≈ A2 ≈ A3 ≈ A5 ≈ A7
	Q	1.0000	0.5106	0.5284	0.0000	0.6596	0.4360	0.9096	A4, A6, A2, A3, A5, A7, A1

5 Conclusions

A common problem researchers encounter when setting up comparisons of different MADM methods is that each method can result to different ranking results. Hence, many researchers apply different MADM methods and compare the corresponding rankings. In this paper, we presented the implementation of a web-based decision support system that incorporates TOPSIS and VIKOR and allows decision makers to compare the results and rankings obtained from both methods. Different techniques are available for each step of these methods. More specifically, decision makers can select the normalization technique (vector or linear), the technique to calculate the ideal and anti-ideal solutions (min/max or absolute values) and the distance measure to be used (Euclidean, Manhattan or Chebyshev) for TOPSIS method and the weight of the maximum group utility strategy (v) for VIKOR method. The results are graphically and numerically displayed, allowing the decision makers to easily compare the rankings obtained by the two methods. Finally, a real-world case study on social sustainability in agriculture was presented. The aim of this study is to classify and rank the rural areas of Central Macedonia in Northern Greece using a set of eight social sustainability indicators. Using the implemented decision support system, decision makers can easily obtain rankings by TOPSIS and VIKOR. In future work, we plan to include fuzzy versions of TOPSIS and VIKOR as well as other MADM methods like PROMETHEE and ELECTRE.

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