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REVIEW

VIKOR Method—An Effective Compromising Ranking Technique for Decision Making

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ABSTRACT

The VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method, which is a multi-criteria decision-making method, is examined in this paper. The VIKOR method, like other MCDM techniques such as the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), is widely used to solve complex decision-making problems in various fields such as engineering, management, and finance. This paper provides an overview of the VIKOR method, including its application areas, advantages, and disadvantages. Besides, in this survey paper, the process steps of the VIKOR method are described, including determining the decision matrix, normalizing the matrix, determining the weights of the criteria, calculating the utility and regret values, calculating the VIKOR index, and finally ranking the alternatives. By providing an overview of the VIKOR method and its process steps, this paper aims to provide a better understanding of the method and its potential application in different decision-making contexts.

Keywords: Decision making; Multi criteria decision making; VIKOR method; VlseKriterijumska Optimizacija I Kompromisno Resenje; Multi attribute decision making

1. Introduction

Multi-attribute decision making (MADM) methods can be used to solve most decision-making problems with contradictory and multiple evaluation standards [1]. These methods assist the managers and decision-makers with different dimensions of a problem, which allows them to evaluate all probable options and consider different elements and under variable degrees in the decision making which is a vital aspect of individuals' life [2]. There are different qualitative and quantitative MADM techniques.

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The compromise ranking method known as VIKOR "VlseKriterijumska Optimizacija I Kompromisno Resenje" is one of the main and effective MADM tools used to select an alternative among different options by considering several criteria [1]. This method works based on introducing a ranking index considering the closeness to an ideal solution using a specific measure [3-5]. Therefore, the basis of this method is similar to TOPSIS (based on distances to the ideal solution [6]), although there are some differences that will be discussed in the following sections [7-9]. Furthermore, this method does not consider bias toward a particular option, and a compromise is made between possibilities, desires, as well as the decision makers' interests. The VIKOR method seeks to identify the most suitable alternative from a range of viable options by balancing the ideal and anti-ideal solutions. This approach takes into account several criteria and aims to achieve the best possible outcome. One of the significant benefits of the VIKOR method is its capability to manage insufficient or conflicting data while accommodating both quantitative and qualitative aspects. Nevertheless, the method also has certain limitations, such as its susceptibility to fluctuations in the criteria weightings, which can impact the ranking outcomes.

This compromise solution is based on examining the narrower range of viable solutions that approach the ideal solution based on their values, for example, a reference point that is in the criteria functions' space. Usually, these criteria consider maximum profit and minimum costs (expenses), although other concepts and dimensions such as energy and services also can be included. Generally, the criteria include different qualitative and quantitative aspects such as technical and economic criteria, which can be either quantitative or qualitative. On the other hand, the criteria functions can be expressed by using different measuring units, and this difficulty to make the comparison between alternatives must be addressed in decision making [5].

To sum, the VIKOR provides a multi-criteria ranking index based on the closeness to the ideal solution and aims to determine:

- the compromise ranking list;
- the compromise solution;
- the weight stability intervals.

Here, the weight stability intervals are determined for the compromise solution's preference stability which is gained with the initial (given) weights [8].

The following sections are provided to review the VIKOR method in more detail. For this, first, the main differences between the TOPSIS and VIKOR will be described, then the application areas, advantages, and disadvantages are listed. The process steps also are explained in the last section.

2. VIKOR vs. TOPSIS

As discussed, both methods work based on the closeness of options to an ideal point. However, there are several differences between them that are summarized in **Table 1**.

Table 1. TOPSIS and VIKOR differences [9].

Features	TOPSIS	VIKOR
Normalization Method	vector normalization	linear normalization
Compromise Solution Basis	Based on a maximum "group utility" for the "majority" and a minimum of an individual regret for the "opponent".	Based on the shortest distance to the ideal solution and the greatest distance from the negative-ideal solution without considering the relative importance.
Aggregation and Ranking Index	The ranking index includes the distances from the ideal point and the nadir (negative-ideal) point. One of the main concerns is to determine the reference point and the issues related to eliminating the role of relative importance in this method.	Introduces a function for aggregation that shows the distance from the ideal solution. Here, the ranking index is "an aggregation of all criteria, the relative importance of the criteria, and a balance between total and individual satisfaction".
Solution	The best alternative in the ranking index has the highest rank, but it is not always the alternative with a minimum distance from the ideal point.	The closest alternative to the ideal solution has the highest rank.

3. Application areas of VIKOR

MADM methods are applicable in different areas. The VIKOR method also can be applied in manifold subject areas such as engineering, supply chain and health care. The distribution of the subject areas of the VIKOR method based on searching the "VIKOR" title in the "ScienceDirect" database (including the research articles with "VIKOR" title in their "title, abstract, or keywords") is shown in **Figure 1**:

To discuss the application areas more specifically, the results of a literature review by Mardani et al. [10] are summarized here. They classified the application fields into 15 different categories. The summary is shown in **Table 2**.

4. Advantages and disadvantages of VIKOR

As can be seen in other MADM methods, the VICOR also possesses different advantages and disadvantages. One of the main positive points in the VIKOR is reflecting most decision makers' attributes by determining a compromise solution [3]. The other

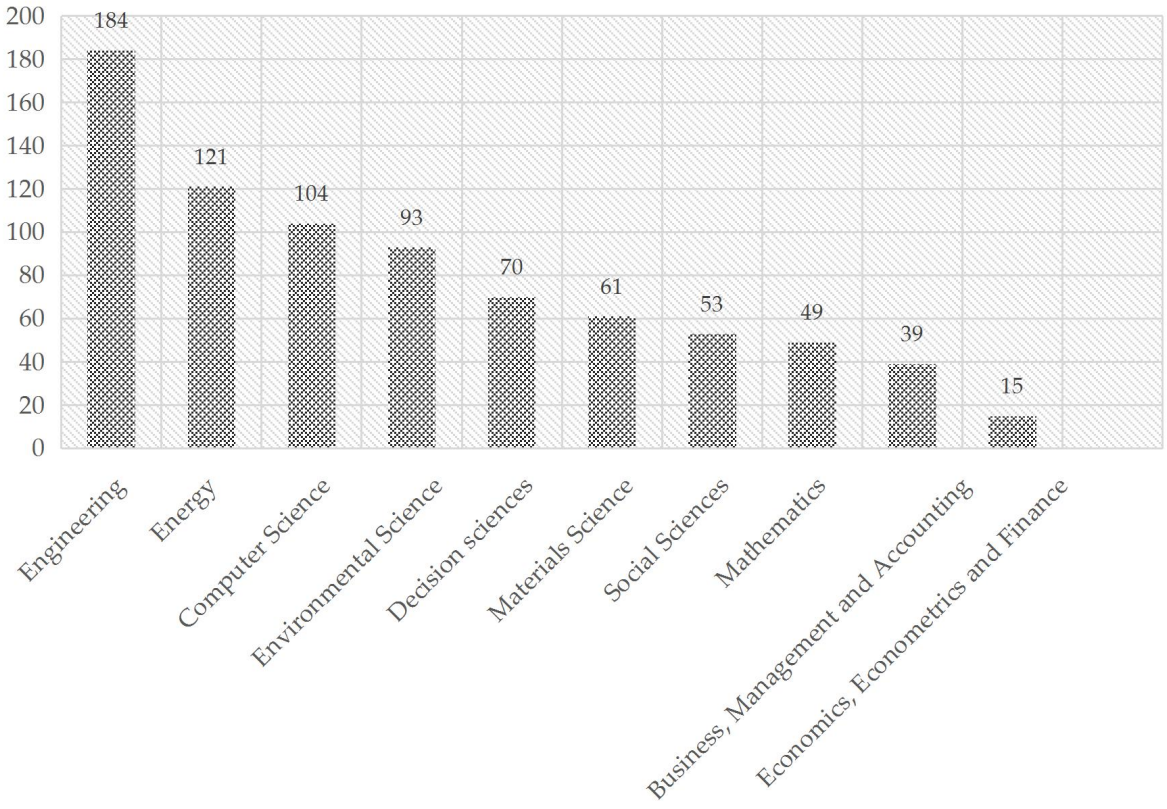

Figure 1. Distribution of the VIKOR subject areas.

Table 2. Application areas of the VICOR method.

Application Area	Description
Manufacturing	The articles in different sub-areas such as manufacturing systems, machine tools, product design, robot selection, strategies of manufacturing, and development of products.
Construction Management	This area includes project management, transportation systems, building fields, and tunneling sub-areas.
Material Selection	The articles aim to select materials for different purposes such as pipeline material, materials for transducer application, etc.
Performance Evaluation	This area includes the performance evaluation of banks, universities, businesses as well as engineering departments.

Table 2 continued

Application Area	Description
Health-Care	The studies consider the healthcare management and healthcare waste disposal fields.
Supply Chain	This field covers different sub-areas including supply chain networks, selection of suppliers, and the performance of the supply chain.
Tourism	The studies are about tourism development and its policies.
Service Quality	It includes electronic quality of services, airlines as well as service quality improvement areas.
Sustainability and Renewable Energy Fields	This area considers energy resources, environmental management and evaluation, and the assessment of life cycle sustainability.
Water Resources Planning	The subjects aim to develop, plan, manage and distribute water resources based on optimal usage.
Marketing	Marketing includes outsourcing providers, portfolio selection, brand marketing, and also strategy evaluation sub-areas.
Risk and Financial Management	The subjects aim to evaluate the risks in different processes, study information security, and also consider the financial performance improvement and financial assessment areas.
Operation Management	It is about city logistics, knowledge management, selection of concepts, process performance, and benchmarking fields.
Human Resource Management (HRM)	The sub-areas such as evaluation of HRM systems, corporate social responsibility, intellectual capital as well as customer satisfaction are considered.
Other Areas	Other areas such as the leachate treatment process, network selection, flood management, etc. are studied.

merits of the VIKOR can be listed as:

- It has a very simple ranking procedure with a small number of steps [3];
- It considers minimum individual regrets and maximum group benefits to gain an acceptable compromise solution;
- A consistency check is not required in this method [11].

On the other hand, it possesses different demerits. The main is that the VIKOR searches for the compromise ranking order, for example between expected solution and pessimistic. Therefore, changing the solutions' weights can impact the ranking as the results of the solution. Although, the noted demerit is considered an advantage by some authors. Because, changing the weights of the expected solution and pessimistic a significant factor, it could be possible to identify how the impacts on the coefficient of weights can affect the alternatives' ranking. Another disadvantage is the necessity of using a complex linear normalization method in a specific step to gain dimensionless units in the decision matrix (as other methods are not suitable). However, modifications are suggested that can make using other normalization methods possible in some situations [5,12].

To improve the traditional VIKOR concept, various variants are suggested by several authors. For example, variants such as Comprehensive VIKOR, Fuzzy VIKOR, Regret VIKOR, and a modified model have been proposed and analyzed by Chatterjee and Chakraborty [13] in order to determine the suitability of different VIKOR variations for various decision-making problems. Based on their results, Fuzzy VIKOR, for instance, is recommended when the information is imprecise.

5. VIKOR process steps

The process of conducting the VIKOR method includes different steps (shown in **Figure 2**). The variables used in the equations are defined first as:

- a_j is the alternative, j = 1,2, ..., J and J is the number of alternatives;
- f_i is the criterion i = 1,2, ..., n and n is the number of criteria;
- f_{ij} is the value of i^{th} criterion function for the

alternative a_j;

- w_i is the weights of the *i*criterion expressing the relative importance of the criteria.

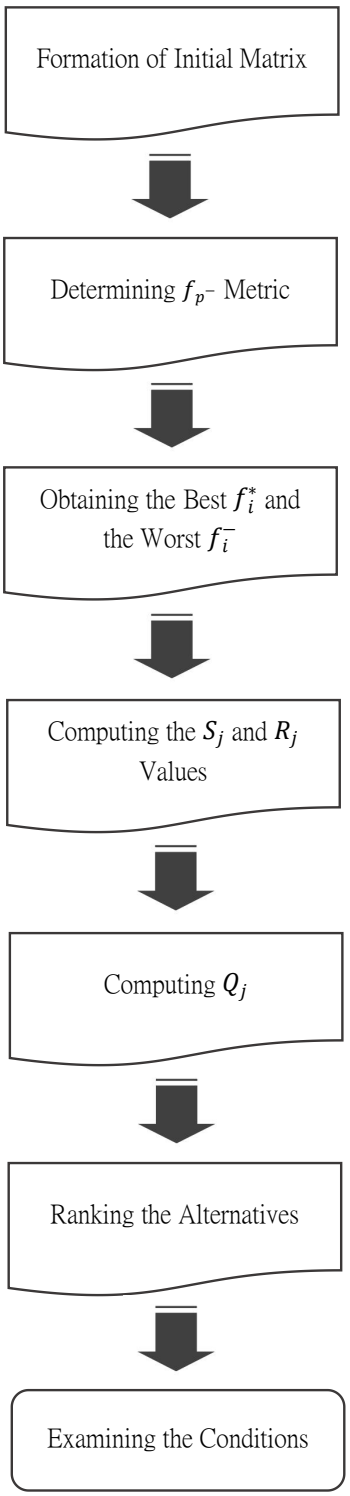

Figure 2. VIKOR process steps.

Step 1. Formation of Initial Matrix

The VIKOR process starts with providing a decision table followed by an initial decision matrix to show the alternatives, criteria, and their weights.

Step 2. Determining L_p-metric

An assumption in this method is to evaluate each alternative based on each criterion and use a compromise ranking comparing closeness to the ideal alternative. For this, L_p-metric is used as an aggregating function to develop the multi-criteria measure for compromise ranking. L_p-metric is calculated as Equation (1):

$$L_p = \left\{\sum_{i=1}^{n}\left[w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)\right]^p\right\}^{1/p} \quad (1)$$

$$where\ 1 \le p \le \infty\ and\ j = 1,2,3,\ldots,J.$$

In the VIKOR process, L_{1j} and $L_{\infty j}$ (as S_j and R_j in Equations (2) and (3); respectively) are used for ranking measure formulation in the next steps. Furthermore, the solutions gained by $min_j S_j$ and $min_j R_j$ are with "a maximum group utility known as majority rule" and "a minimum individual regret of the opponent"; respectively. Ideal and compromise solutions are shown in **Figure 3**. In this figure, F^c is the compromise solution which is the closest feasible solution to the ideal solution (F^*), and compromise means an agreement based on mutual concessions. These concepts are shown in the figure and can be illustrated as:

$$\Delta f_1 = f_1^* - f_1^c\ and\ \Delta f_2 = f_2^* - f_2^c$$

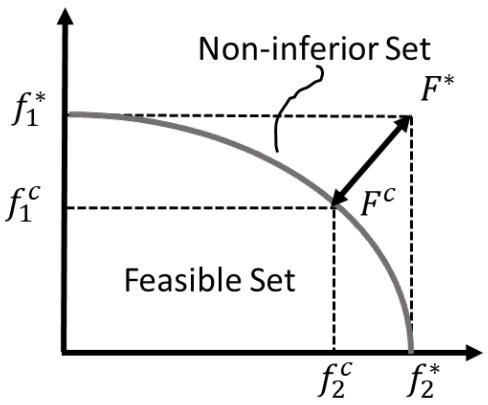

Figure 3. Ideal and compromise solutions in the VIKOR method [9].

After recognizing the compromise concept better, the VIKOR algorithm to gain the compromise ranking is described in the next following steps.

Step 3. Obtaining the Best f_i^* and the Worst f_i^-

In this step, the values of f_i^* and f_i^- for all criterion functions must be determined. For this, $f_i^* = \max_j f_{ij}$ *and* $f_i^- = \min_j f_{ij}$, when a benefit is represented by the i^{th} function.

Step 4. Computing the S_j and R_j values

Equations (2) and (3) are used to gain the values of S_j and R_j:

$$S_j = \sum_{i=1}^{n} w_i(f_i^* - f_{ij})/(f_i^* - f_i^-);\ i = 1,2, ..., n. \quad (2)$$

$$R_j = \max_i [w_i(f_i^* - f_{ij})/(f_i^* - f_i^-)];\ i = 1,2, ..., n. \quad (3)$$

Step 5. Computing Q_j

This value is obtained using the following equation:

$$Q_j = \frac{\vartheta(S_j - S^*)}{(S^- - S^*)} + (1-\vartheta)\frac{(R_j - R^*)}{(R^- - R^*)};$$
$$If:\ Q_{Sj} = \frac{(S_j - S^*)}{(S^- - S^*)}\ and\ Q_{Rj} = \frac{(R_j - R^*)}{(R^- - R^*)} \quad (4)$$

Then:

$$Q_j = \vartheta Q_{Sj} + (1-\vartheta)Q_{Rj}; \quad (5)$$

In Equation (4):

$$S^* = \min_j S_j;\ S^- = \max_j S_j;\ R^* = \min_j R_j;\ R^- = \max_j R_j.$$

In Equation (4), ϑ is "the weight of satisfying most criteria" based on the weight of the strategy of "the majority of criteria" or "the maximum group utility". On the other hand, $(1 - \vartheta)$ is "the weight of the individual loss of opportunity".

In the above equation, three ranking lists are formed as follows:

- Q_{sj} is "the measure of deviation which expresses the demand for maximum group benefit".
- Q_{Rj} is "the measure of deviation which expresses the demand for minimization of maximum distance between some alternative from the ideal point".
- Q_j is "the establishing of compromise ranking list which unifies units Q_{sj} and Q_{Rj}".

Step 6. Ranking the Alternatives

The results of this step are three ranking lists (as discussed in the previous step). The alternatives should be ranked based on the values of Q_{sj} , Q_{Rj}, and Q_j in decreasing order. For example, a_j is better than a_t, if $Q_j < Q_t$.

Step 7. Examining the Conditions

After ranking the alternatives, the last step to gain the compromise solution is to examine whether the selected alternative *a*' (with minimum *Q*) fulfills the following conditions or not:

- Condition 1: The first condition known as "acceptable advantage" examines the following condition:

$$Q(a'') - Q(a') \geq 1/(J-1) \quad (6)$$

where *a*" is the second alternative in the list of ranking.

- Condition 2: The second condition is "the acceptable stability in decision making" and can be satisfied when the alternative *a*' (ranked first in the *Q*) is also the first in the *S* or/and *R* ranking lists.

When one of the above conditions are not satisfied the following decisions are made to find a set of compromise solutions:

- If just condition 1 is satisfied, then *a*' and *a*" are in the final compromise solution set.
- If just condition 2 is satisfied, then *a*', *a*", …, $a^{(h)}$ is the alternative set. *h* is a position number in the ranking list when the condition $Q(a^{(h)}) - Q(a) < 1/(J-1)$ is verified using $a^{(h)}$ [3,5,7,9].

6. Conclusions

In conclusion, the VIKOR MADM method is a useful tool for decision-making in various application areas, ranging from supply chain management to healthcare and water resources planning. The main advantages of VIKOR include its ability to provide a compromise solution that takes into account multiple criteria and its ability to rank alternatives based on their distance from the ideal solution. However, VIKOR also has some disadvantages, such as its sensitivity to the weight coefficients assigned to the criteria and its lack of flexibility in dealing with uncertain and imprecise information.

The comparison between VIKOR and TOPSIS revealed some important differences between the two methods. While both methods aim to provide a

compromise, solution based on multiple criteria, they differ in terms of their normalization methods, the basis of their compromise solution, aggregation, and ranking index. Specifically, VIKOR uses a ranking index based on the concept of "closeness to the ideal solution", whereas TOPSIS uses a ranking index based on the concept of "closeness to the average solution" [6].

Overall, the VIKOR MADM method can be a valuable tool for decision-makers who need to evaluate alternatives based on multiple criteria. The process steps involved in using VIKOR, including defining the decision problem, selecting the criteria and alternatives, normalizing the criteria values, calculating the VIKOR scores, and ranking the alternatives, are straightforward and can be easily implemented using various software tools.

Conflict of Interest

There is no conflict of interest.

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