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ORIGINAL RESEARCH ARTICLE

A comprehensive guide to the TOPSIS method for multi-criteria decision making

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ABSTRACT

One common multi-criteria decision making (MCDM) technique is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which is frequently applied in several application fields. Finding an ideal and an anti-ideal solution, which are then utilized to determine the distances between the alternatives and the ideal solution, is the foundation of the TOPSIS approach. The method then ranks the alternatives according to their closeness to the ideal solution. TOPSIS is able to handle both quantitative and qualitative criteria, however, the method can be sensitive to the weight of the criteria, and the ranking results can be influenced by the choice of the reference alternatives. This paper provides an overview of the TOPSIS method, its applications, main characteristics and limitations. The paper also provides step-by-step instructions on how to apply the TOPSIS method, including the determination of the criteria weights, the construction of the decision matrix, and the calculation of the TOPSIS scores.

Keywords: decision making; multi-criteria decision making; Technique for Order of Preference by Similarity to Ideal Solution; TOPSIS method

1. Introduction

Multi-criteria decision making (MCDM) deals with decision making problems with manifold objectives that can be also conflicting usually[1]. The role of MCDM in different fields has increased over the last decades as several authors developed new methods and improved the existing ones[2].

The "Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)" was first established by Hwang and Yoon[3] and is one of the most widely used MCDM methods, and then improved and modified by several authors. For this purpose, they used different modifications, fuzzy environment, and integrated methods (using other MCDM such as AHP). TOPSIS is a useful multi-attribute decision making (MADM) method that deals with real decision problems in human lives by analyzing, comparing, and ranking the alternatives to choose the best and the most suitable option considering the criteria of the problem.

This strategy primarily bases decisions on the alternative that is the furthest away from an anti-ideal option and the closest to an ideal point[4]. This process is simple and programmable, and this makes TOPSIS an easy-to-use and a very popular method. Furthermore, the number of steps for the process is constant, and it is not

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related to the number of attributes. However, it possesses different demerits. This method can be used for decision making in different fields such as engineering design, manufacturing and management of supply chain, human resources and water resources[2,5]. The following sections will delve into the specific application areas, advantages, and disadvantages of TOPSIS. Moreover, the model will be explained, outlining the six main fundamental steps involved in this method.

2. Application area

As discussed, in recent years, this method successfully has been used for manifold areas. Different articles provided literature reviews on the application areas used TOPSIS to optimize their processes. For example, Shih et al.[4] listed eleven studies used TOPSIS as an MCDM method in different applications. Behzadian et al.[6] provided a list for different subject areas that TOPSIS is used in them and analyzed the distribution of papers in those fields. Shukla et al.[7] also reviewed twelve studies highlighting the role of TOPSIS algorithms in manufacturing processes. In 2018, Yadav et al.[8] conducted a comprehensive review encompassing numerous research articles that employed TOPSIS for decision making in various industries. **Table 1** summarizes the results of these reviews, clearly demonstrating the diverse range of application areas where TOPSIS has been utilized in recent years.

Table 1. TOPSIS application areas.

Authors	**Application areas/examples**
Shih HS et al.[4]	Company financial ratios comparison, expatriate host country selection, manufacturing plant location analysis, robot selection, water management, gear material selection, solid waste management, facility location selection, etc.
Behzadian M et al.[6]	Supply chain management and logistics, design, engineering and manufacturing systems, chemical engineering, energy management, human resources management, safety and environment management, health, business and marketing management, water resources management, etc.
Shukla A et al.[7]	List of the manufacturing processes: powder mixed electro discharge machining, face milling, drilling, abrasive water jet cutting, electric discharge machining (edm), turning process, etc.
Yadav SK et al.[8]	List of the industries: airline, automobile, finance and banking, food, biological and human behavior, information technology (it), rehabilitation, different manufacturing processes such as selection of supplier, location, and technology.

3. Advantages and disadvantages

TOPSIS method has a simple process that makes it easy to program and use and a very popular method among researchers in this field. It is also a very efficient technique with widespread application. However, the negative points must not be underestimated. The main advantages and disadvantages are discussed in this section.

The advantages of TOPSIS were discussed by Shih et al.[4]. They listed the merits of this method as:

- TOPSIS can represent the rationale of human choice.
- Scaler value of TOPSIS can account simultaneously for the best as well as worst alternatives.
- It has a simple computation process that makes programming on a spreadsheet possible.
- As discussed before, the number of attributes does not affect the number of TOPSIS process steps.
- A polyhedron can be used to visualize the performance measures of the attribute and alternatives of the problem (for two or more dimensions)[2,4].

All these merits make TOPSIS a major MCDM method. However, traditional TOPSIS faces different disadvantages regardless of the following issues:

- It uses the Euclidean Distance without considering the correlation of attributes. Therefore, information overlap can impact the results.
- In this method weighing is a difficult and uncertain process.
- It is possible to face alternatives that are close to positive and negative ideal points concurrently.
- It sometimes is not able to determine uncertain data precisely due to the possibility of vague human judgments when the information is not sufficient.
- Finally, an important issue is related to the rank reversal phenomenon. This phenomenon happens due to the changes in the alternatives' ranking by adding an alternative, adding a criterion, or dropping one of them. On the other hand, ranking index applies the distances from negative and positive ideal points without considering the weights or relative importance of the distances[9–11].

To sum, although TOPSIS is an applicable easy MCDM method, different criticisms such as its low-level rank reversal compared with many other MCDM methods led to the development of several TOPSIS-based modified and fuzzy methods, and traditional TOPSIS is opted as the main body of development[4,11].

4. TOPSIS model

TOPSIS is known as an effective MCDM method due to the specific characteristics of this technique which make it a high consistent method with less effort for computation. Basically, the multi-response values are combined in this approach to provide a single performance response value.

In TOPSIS technique the aim is to gain an order preference that is similar to the ideal solution which is a hypothetical solution with maximum benefits and minimum costs of attributes or alternatives. On the other side, a fictitious solution known as the negative ideal solution would increase the costs of the traits or criteria while minimizing their benefits. Thus, the best alternative, which is also the solution to the problem, is the one that is nearest to the positive ideal solution and farthest from the negative one. This similarity or difference are described by the Euclidean Distance/Geometric Distance and the ideal solution, and the negative ideal are examined based on the maximum/minimum values of the database. In this method, with its more realistic modeling form, trade-offs are possible between the criteria as it allows to neglect a poor result considering one criterion by good results in another one[5,7]. In all MCDM problems, an $m \times n$ decision matrix with m alternatives and n criteria is considered as below:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}_{m \times n}$$

In all equations in this section, $i = 1, \ldots, m$ and $j = 1, \ldots, n$. The problem can also include a vector for criteria weights as $W = (w_1, \ldots, w_n)$ that must satisfy the following equation (Equation (1)):

$$\sum_{j=1}^{n} w_j = 1 \tag{1}$$

The process of choosing the best alternative by using TOPSIS technique can be described in 6 main steps that are described following, and also is shown in **Figure 1.**

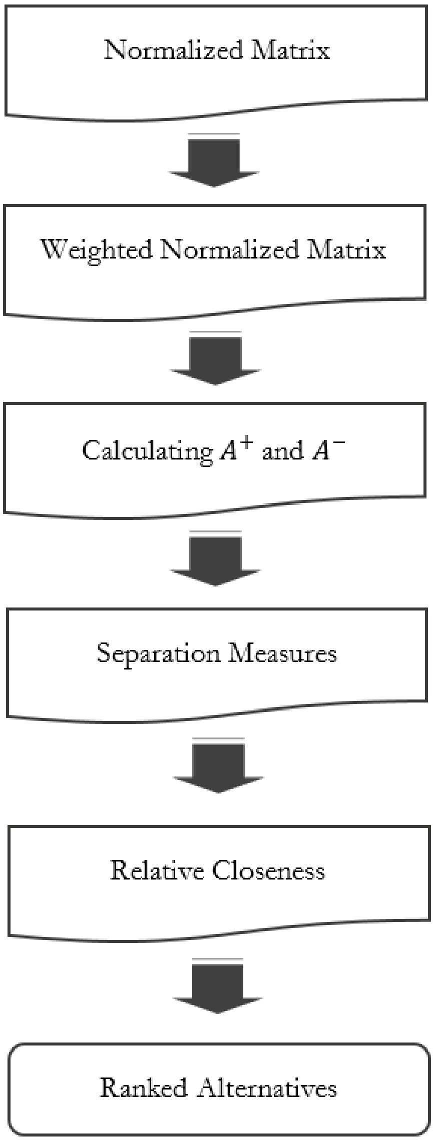

Figure 1. TOPSIS method steps.

Step 1: Normalizing the decision matrix

There are different kinds of criteria with different units in each MCDM problem. To compare those criteria, they need to be dimensionless (without units), and this is possible using the normalization process. Several methods can be utilized for this purpose. Shih et al.[4] listed manifold linear and non-linear normalization methods, but here a common method is presented. For example, the normalized values for each x_{ij} in the decision matrix by using vector normalization technique is shown as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} {x_{ij}}^2}} \quad (2)$$

Step 2: Calculating the weighted normalized matrix

The weighted normalized decision matrix (V) can be calculated as:

$$V = (v_{ij})_{n \times m} \quad (3)$$

where $v_{ij} = w_j r_{ij}$.

Step 3: Determining the positive ideal and negative ideal solutions

Positive ideal solution that is also known as Zenith (A^*) and Negative ideal solution known as Nadir or anti-ideal (A^-) solutions are calculated in this step. Although, these solutions can be simply determined by the decision maker/s, it can add more subjectivity to the process, they can be obtained as the absolute form of positive and negative ideal as:

$$A^* = \{1,1,1,\ldots,1\}$$

$$A^- = \{0,0,0,\ldots,0\}$$

The following equations also are recommended to obtain negative and positive ideal solutions:

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} = \{(^{max}{}_j v_{ij} \mid i \in I'),(^{min}{}_j v_{ij} \mid i \in I'')\} \quad (4)$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{(^{min}{}_j v_{ij} \mid i \in I'),(^{max}{}_j v_{ij} \mid i \in I'')\} \quad (5)$$

These equations show that the A^* is given from collecting the best performances of V, and A^- instead comes from the worst performances of the normalized matrix.

Step 4: Calculating the separation measures

After determining the negative and positive solutions, in this step the distance of the alternatives with A^* and A^- are calculated. There are different ways to calculate the distances, and one of the more popular ones known as the classical Euclidean Distance is used here:

$$D_i^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2} \quad (6)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \quad (7)$$

Step 5: Calculating the relative closeness

The range of the Relative closeness factor is between 0 and 1, and is calculated using the following equation:

$$C_i^* = \frac{D_i^-}{D_i^+ + D_i^-} \quad (8)$$

Step 6: Ranking the alternatives

In the final step of TOPSIS, the alternatives are ranked from the best with the biggest C_i^* (that is also the closest C_i^* value to 1) to the worst alternative, with the lowest C_i^*. The top alternative in the list that is the alternative with the biggest C_i^* value is the solution[5,7,12]. Papathanasiou and Ploskas[12] provided numerical examples that can be beneficial to learn this method better.

5. Conclusion

TOPSIS is a widely-used multi-criteria decision-making method that has several advantages, such as being able to represent human choice and having a simple computation process. However, it also has several disadvantages, including its use of the Euclidean Distance without considering the correlation of attributes, difficulties in the weighting process, and the possibility of rank reversal. Despite these limitations, TOPSIS remains a popular and practical method for solving complex decision-making problems.

This study has provided a brief overview of the history and applications of TOPSIS and has analyzed its main advantages and disadvantages. Additionally, the study has described the TOPSIS process in a simple and easy-to-understand way. Overall, TOPSIS is a useful method for tackling complicated decision-making problems, as seen by the several modified and fuzzy TOPSIS algorithms that have been created. Future studies could concentrate on improving the TOPSIS technique to overcome its limitations and make it an even more powerful decision-making tool.

Author contributions

Conceptualization, HT and MM; methodology, HT; validation, HT; resources, MM; writing—original draft preparation, MM; writing—review and editing, MM; visualization, MM; supervision, HT. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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