# Comparative analysis of multicriteria methods based on single-valued neutrosophic numbers for the evaluation of medical technologies

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**Abstract**

Decision-makers are often faced with complicated decision problems with intangible and conflicting criteria. Many methods are proposed to handle the inclusion of many and varied criteria that allow choosing the best alternative for a decision. The public health sector daily faces numerous complex situations that require the facilities provided by multicriteria methods. This research proposes a comparative analysis of multicriteria methods for the selection of health technologies. With this, it is proposed to check to what extent the selected MCDAs are capable of offering consistent results among themselves. Comparisons are made using the TOPSIS method and a modification of the PROMETHEE method, both in their neutrosophic versions, by using single-valued neutrosophic numbers. The results showed that both methods coincided in the order of preference given to each treatment. However, it is observed that the method based on PROMETHEE yields more detailed information on the elections' interiorities. The effectiveness of the methods used can be verified and their practical and feasible application in complex medical problems.

**Keywords**: multicriteria analysis; TOPSIS, neutrosophic PROMETHEE; medical technologies

## 1. Introduction

The constant technological evolution that the world is undergoing today is increasingly accelerated. Recent decades have been full of changes in various areas of society and technology, which have permanently altered customs, communities, and ecosystems. Recent innovations have demonstrated the power of technology as one of the most powerful agents of social change in modern times. This power of change implies the need to make unprecedented, complex, and often contradictory decisions for decision-makers worldwide.

In the health field, the situation is even more complex since health systems are faced with the task of achieving the greatest clinical benefits, equity in access, quality, and opportunity in care, and guaranteeing the fundamental right to the health and sustainability of the system, counteracting, for example, changes in demographic and



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epidemiological profiles, the needs and preferences of the population, the increase in the level of innovation in health technologies, the high costs of these new technologies and budgetary restrictions.

In such a context, a correct evaluation of the available health technologies is essential for medical personnel, hospital staff, and those who will benefit from each of these technologies. As in any other field of science, to carry out quality evaluations and that provide useful information for decision-making, in this sector, it is necessary to have solid and reproducible methodologies for making pertinent and robust decisions appropriate to the system of health and the circumstance to be treated.

Traditionally, to optimize resources, decision-making was based only on applying or obtaining the lowest-cost technology or proposing the best cost-benefit or cost-effectiveness ratio. However, although the effectiveness and costs of health technologies represent a necessary factor for their evaluation, they are not sufficient. In such a scenario, multicriteria decision analysis (MCDA) methods can evaluate health benefits far beyond just cost-effectiveness.

These methods reduce subjectivity in decision-making by creating a series of selection filters and helping to choose between complex alternatives. Moreover, they can help analyze the problem, task, or objective by breaking it down into a finite number of requirements, and once the requirements are established, they help to rank them by the relative importance or weight of each criterion for each alternative. Hence, they help improve the quality of decisions by creating a more rational and efficient decision-making process [1].

Considering those above, this study proposes a comparative analysis of multicriteria methods for selecting health technologies. With this, it is proposed to check to what extent the selected MCDAs can offer consistent results among themselves. To eliminate the vagueness inherent to the real world, this study will be developed by using the contributions made by the branch of neutrosophy and their contributions in terms of neutrosophic sets [2], see also [9–12].

Two multicriteria decision methods are selected to compare their results to carry out the proposed analysis. On the one hand, the TOPSIS method (*Technique for Order Preference by Similarity to Ideal Solution*) is a technique used for decision making, developed in 1981 by Hwang and Yoon [7], which has been extended to the neutrosophic environment [14–18]; and on the other, a modification to the PROMETHEE method carried out by [13] which includes the use of single-valued neutrosophic sets for the analysis, see also [14]–[17].

TOPSIS is based on the premise that the decision-makers optimal alternative must have the smallest Euclidean distance to an ideal solution and the greatest Euclidean distance to an anti-ideal solution. This method allows several heterogeneous attributes to be combined into a single dimensionless index since the attributes under evaluation are often expressed in different units or scales [18], [19]. Thus, the methodology based on neutrosophic TOPSIS proposed by [20] is appropriate to the needs of the selection of health technologies. The use of Neutrosophy to solve medical problems can be read in [23–26].

The proposal made by [13] is based on the input and output calculation formula in the PROMETHEE method and the global dominance calculation formula in the TODIM method, which allows for obtaining a new integrated formula.This proposal does not require that the distance between the alternatives be calculated, nor does it require that two alternatives be compared, which reduces the amount of calculation to an enormous degree. In addition, by using the general domain and general handicap to calculate the entry and exit, the credibility of the alternative ranking is increased [13]. It is incorporating the neutrosophic sets in the selected methods guarantees that the uncertainty of decision-making is taken into account, including indeterminacies.



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## 2. Preliminaries

**Definition 1.** Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function $TA\ (x)$, indeterminacy-membership function $IA\ (x)$, and falsity membership function $FA\ (x)$. Then, an SVNS A can be denoted by $A\ =\ \{x, TA\ (x), IA\ (x), FA\ (x)\ x\ \in\ X\}$, where $TA\ (x), IA\ (x), FA\ (x)\ \in\ [0,1]$ for each point x in X. Therefore, the sum of $TA\ (x), IA\ (x)$ and $FA\ (x)$ satisfies the condition $0\ \leq\ TA\ (x)\ +\ IA\ (x)\ +\ FA\ (x)\ \leq\ 3$, [13].

For convenience, an SVNN is denoted by $A\ =\ (abc)$, where a, $b, c\ \in\ [0,1]$ and $a\ +\ b\ +\ c\ \leq\ 3$

**Definition2**. Let $A1\ =\ (a1, b1, c1)$ and $A2\ =\ (a2, b2, c2)$ be two SVN numbers, then addition between A1 and A2 is defined as follows:

$$A1\ +\ A2\ =\ (a1\ +\ a2 - a1a2, b1b2, c1c2) \qquad (1)$$

**Definition3**. Let $A1\ =\ (a1, b1, c1)$ and $A2\ =\ (a2, b2, c2)$ be two SVN numbers, then multiplication between A1 and A2 is defined as follows:

$$A1\ *\ A2\ =\ (a1a2, b1\ +\ b2\ -\ b1b2, c1\ +\ c2\ -\ c1c2) \qquad (2)$$

**Definition 4**. Let $A\ =\ (a, b, c)$ be a SVN number and $R$ an arbitrary positive real number, then:

$$A = \left(1 - (1 - a)\ \ , b\ \ , c\ \ \right), > 0 \qquad (3)$$

**Definition 5**. Let $A = \{A_1, A_2, \ldots, A_n\}$be a set of n SVN numbers, where $Aj\ =\ (aj, bj, cj)\ (j\ =\ 1,2, \ldots, n)$. The single value neutrosophic weighted average operator on them is defined by

$$\sum_{j=1}^{n}\ \ {}_{j}A_j = \left(1 - \prod_{j=1}^{n}\ \ (1 - a_j)^{\ \ j}, \prod_{j=1}^{n}\ \ b_j^{\ \ j}, \prod_{j=1}^{n}\ \ c_j^{\ \ j}\right)$$
(4)

Where ${}_{j}$ is the weight of $Aj\ (j\ =\ 1,2, \ldots, n)$, ${}_{j} \in [0,1]$and$\sum_{j=1}^{n}\ \ {}_{j} = 1$

Decision-making typically involves human language or is commonly referred to with linguistic variables. A linguistic variable simply represents words or terms used in human language. Therefore, this linguistic variable approach is convenient for decision-makers to express their assessments. For example, ratings of criteria can be expressed by using linguistic variables such as very important (VI), important (I), low important (LI), not important (NI), etc. Linguistic variables can be transformed into SVNSs as shown in Table 1.

Table 1: Linguistic variable and Single Valued Neutrosophic Numbers (SVNNs). [25]

| Integer | Linguistic variable | SVNNs |
|---|---|---|
| **0** | No influence / Not important | (0.9; 0.1; 0.1) |
| **1** | Low influence / important | (0.75; 0.25; 0.20) |
| **2** | Medium influence / important | (0.50; 0.5; 0.50) |
| **3** | High influence / important | (0.35; 0.75; 0.80) |
| **4** | Very high influence / important | (0.10; 0.90; 0.90) |



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**Definition 6.** Let $Ak = (ak, bk, ck)$be a SVNN defined for the rating of k-th decision-maker. Then, the weight of the k-th decision-maker can be written as:

$$\psi_k = \frac{1-\sqrt{[(1-a_k)^2+(b_k)^2+(c_k)^2]/3}}{\sum_{k=1}^{p} \sqrt{[(1-a_k))^2+(b_k)^2+(c_k))^2]/3}} \tag{5}$$

Further, group decision-making is important in any decision-making process in achieving a favorable solution. Therefore, all the individual decision-maker assessments need to be aggregated to one aggregated neutrosophic decision matrix in the group decision-making process. This can be done by employing a single-valued neutrosophic weighted averaging (SVNWA) aggregation operator proposed by Ye [26].

**Definition7.** Let $D(k) = (dij(k))mxn$ be the single-valued neutrosophic decision matrix of the k-th decision-maker and $\psi = (\psi_1 \psi_2, \dots, \psi_p)^T$ be the weight vector of decision-maker such that each $\psi_k \in [0,1], D = (d_{ij})_{mxn}$ where

$$d_{ij} = \langle 1 - \prod_{k=1}^{p} \left(1 - a_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p} \left(b_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p} \left(c_{ij}^{(p)}\right)^{\psi_k} \rangle \tag{6}$$

**Definition 8**. Let $A^* = \{A_1{}^*, A_2{}^*, \dots, A_n{}^*\}$ be a vector of n SVN numbers, such that $Aj *= (aj *, bj *, cj *)$ $(j = 1,2, \dots, n)$, and $B_i = \{B_{i1}, B_{i2}, \dots, B_{im}\}$ (i= 1,2,…,m), (j= 1,2,…,n). Then the separation measure between $B_i$ and $A^*$ based on Euclidian distance is defined as follows:

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n} \left(|a_{ij} - a_j^*|\right)^2 + \left(|b_{ij} - b_j^*|\right)^2 + \left(|c_{ij} - c_j^*|\right)^2\right)^{\frac{1}{2}} \tag{7}$$

(i = 1,2,…, m)

Next, we proposed a score function for ranking SVN numbers as follows:

**Definition 9.** Let $A = (a, b, c)$ be a single-valued neutrosophic number, a score function S of a single-valued neutrosophic value, based on the truth-membership degree, indeterminacy-membership degree, and falsehood membership degree is defined by

$$S(A) = \frac{1+a-2b-c}{2} \tag{8}$$

where $S(A) \in [-1,1]$

The score function S is reduced with the score function proposed by if $b = 0$ and $a + b \le 1$.

**Definition 10.** Let A and B be two SVN numbers, then the normalized Hamming distance between them is:

$$d(A, B) \frac{|a_A - a_B| + |b_A - b_B| + |c_A - c_B|}{3} \tag{9}$$

**Definition 11.** *Let A* = (a, b, c) be a SVN, the complement of SVN A is:

$$AC = (c, 1 - b, a) \tag{10}$$

**Definition 12.** Deneutrosophication[1] of SVNS A can be defined as a process of mapping A into a single crisp output for x$f: A \to \delta^* =\in$. If A is a discrete set then the vector of tetrads $A = \{(x \mid (a, b, c) \mid x \in X\}$ is reduced to a single scalar quantity $\delta * \in X$ by deneutrosophication. The obtained scalar quantity $\delta * \in X$ best represents the aggregate

[1]Deneutrosophication is the process to obtain a crisp number from neutrosophic number. The definition below is the definition of deneutrosophication.



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distribution of three membership degrees of neutrosophic elements a, b, c. Therefore, the deneutrosophication can be obtained as follows.

$$\delta = 1 - \sqrt{[(1-a)^2 + (b)^2 + (c)^2]/3} \tag{11}$$

## 3. Algorithm

The TOPSIS method for SVNS used consists of the following:

Assuming that$A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and$G = \{\beta_1, \beta_2, \dots, \beta_n\}$is a set of criteria, the following steps will be carried out:

**Step 1: Determine the relative importance of the experts**.

For this, the specialists evaluate the alternatives according to the linguistic scale that appears in Table 1, and the calculations are made with their associated SVNN, call At = (at, bt, ct) the SVNS corresponding to the t-th decision-maker (t = 1, 2,…, k). The following formula calculates the weight:

$$\delta_t = \frac{a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)}{\sum_{t=1}^{k} \quad a_t + b_t\left(\frac{a_t}{a_t+c_t}\right)} \tag{12}$$

$$\delta_t \geq 0 \; and \sum_{t=1}^{k} \quad \delta_t = 1$$

**Step 2: Construction of the neutrosophic decision matrix of aggregated unique values.**

This matrix is defined by $D = \sum_{t=1}^{k} \quad \lambda_t D^t$, where $dij = (uij, rij, vij)$ and is used to aggregate all individual evaluations. dij is calculated as the aggregation of the evaluations given by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$, using the weights $\lambda_t$of each one using Equation 4. This way, a $matrix\ D = (dij)ij$ is obtained, where each $dij$ is a SVNN $(i = 1,2,..,m;\ j = 1,2,\dots,n)$.

**Step 3: Determination of the Weight of the Criteria.**

Suppose that the weight of each criterion is given by $W = (w1, w2, \dots, wn)$, where wj denotes the relative importance of the criterion $\lambda_t w_j^t = (a_j^t, b_j^t, c_j^t)$. If it is the evaluation of the criterion $\lambda_t$ by the t-th expert. Then Equation 7 is used to aggregate $w_j^t$ with the weights $\lambda_t$.

single-valued neutrosophic weighted averaging (SVNWA) aggregation

**Step 4: Construction of the neutrosophic decision matrix from the single-valued weighted mean** with respect to the criteria.

$$D^* = D * W, \tag{13}$$

$$where\ d_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

**Step 5: Calculation of the ideal positive and negative SVNN solutions**.

The criteria can be classified as cost type or benefit type. Let G1 be the set of benefit-type criteria and G2 the cost-type criteria. The ideal alternatives will be defined as follows:

The ideal positive solution corresponding to G1.



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$$\rho^{+} = a_{\rho+w}(\beta_j), b_{\rho+w}(\beta_j), ac_{\rho+w}(\beta_j) \quad (14)$$

The ideal negative solution, corresponding to G2.

$$\rho^{-} = (a_{\rho-w}(\beta_j), b_{\rho-w}(\beta_j), ac_{\rho-w}(\beta_j)) \quad (15)$$

Where:

$a_{\rho+w}(\beta_j) = \{max_i a_{\rho iw}(\beta_j), if\ j\epsilon G_1\ min_i a_{\rho iw}(\beta_j), if\ j\epsilon G_2,$
$b_{\rho+w}(\beta_j) = \{max_i b_{\rho iw}(\beta_j), if\ j\epsilon G_1\ min_i b_{\rho iw}(\beta_j), if\ j\epsilon G_2,$
$c_{\rho+w}(\beta_j) = \{max_i c_{\rho iw}(\beta_j), if\ j\epsilon G_1\ min_i c_{\rho iw}(\beta_j), if\ j\epsilon G_2,$

$a_{\rho-w}(\beta_j) = \{min_i a_{\rho iw}(\beta_j), if\ j\epsilon G_1\ max_i a_{\rho iw}(\beta_j), if\ j\epsilon G_2,$
$b_{\rho-w}(\beta_j) = \{min_i b_{\rho iw}(\beta_j), if\ j\epsilon G_1\ max_i b_{\rho iw}(\beta_j), if\ j\epsilon G_2,$
$c_{\rho-w}(\beta_j) = \{min_i c_{\rho iw}(\beta_j), if\ j\epsilon G_1\ max_i c_{\rho iw}(\beta_j), if\ j\epsilon G_2,$

**Step 6: Calculate the distances to the ideal positive and negative SVNN solutions**.

With the help of Equation 7, the following Equations are calculated:

$$d_i^{+} = \left(\frac{1}{3}\sum_{j=1}^{n} \left\{\left(a_{ij} - a_j^{+}\right)^2 + \left(b_{ij} - b_j^{+}\right)^2 + \left(c_{ij} - c_j^{+}\right)^2\right\}\right)^{\frac{1}{2}} \quad (16)$$

$$d_i^{-} = \left(\frac{1}{3}\sum_{j=1}^{n} \left\{\left(a_{ij} - a_j^{-}\right)^2 + \left(b_{ij} - b_j^{-}\right)^2 + \left(c_{ij} - c_j^{-}\right)^2\right\}\right)^{\frac{1}{2}} \quad (17)$$

**Step 7: Calculation of the Coefficient of Proximity (CP).**

The CP of each alternative is calculated with respect to the positive and negative ideal solutions.

$$\widetilde{\rho_J} = \frac{s^{-}}{s^{+}+s^{-}} \quad (18)$$

Where $0 \leq .\widetilde{\rho_J} \leq 1$

**Step 8: Determine the order of the alternatives**.

They are ordered according to what was achieved by $\widetilde{\rho_J}$. The alternatives are ordered from highest to lowest, provided that $\rightarrow$ 1 is the optimal solution.$\widetilde{\rho_J}$

The method proposed by [13] consists of the following:

Let $A = (A1, \dots, Am)$ be the alternatives, and $G = (G1, G2, \dots, Gn)$ the attributes. Let the weights of the attributes be $W = (w1, w2, \dots, wn)$, where $0 \leq wj \leq 1$, $\sum_{j=1}^{n} w_j = 1$. Let $aij, i = 1, 2 \dots m, j = 1, 2, .., n$, be the attribute value of the alternative $A_i$ with attribute $G_j$, the $A = (a_{ij})\ m \times n = \langle (T_{ij}, I_{ij}, F_{ij}) \rangle_{mxn}$ is a SVNNs matrix, where $T_{ij}$, $I_{ij}$, and $F_{ij}$ are membership degree, indeterminacy-membership degree, and non-membership degree. The following is the procedure method

- Step 1: Identify the alternatives to evaluate.
- Step 2. Determine the weights of the decision-makers. The weight of each decision-maker is considered with linguistic variables and is transmitted in SVNN to later be identified using equation (5).
- Step 3: Convert the language assessments given by the SVNN experts. From the individual crisp integer matrixes obtained from the expert evaluations, the individual neutrosophic matrices of the decision-makers are constructed according to what is indicated in Table 1.



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- Step 4. Obtain the initial relation matrix of alternatives $A = (A1, \dots, Am)$ and attributes $G = (G1, G2, \dots, Gn)$, where each aij, i = 1, 2… m, j = 1, 2, .., n, is the value of the attribute of the alternative Ai with the attribute G. The $A = (a_{ij})\ m{\times}n = \langle (T_{ij}, I_{ij}, F_{ij}) \rangle_{mxn}$ is an SVNNs matrix, where Tij, Iij, and Fij are the degree of membership, degree of indeterminacy-membership, and degree of non-membership, using equation (6).
- Step 5: Standardize the decision information. That is, normalize $A = (aij)\, m \times n$ into $B = (bij)\, m \times n$. If the decision is a cost factor, the decision information should be changed to its complementary set using equation (10), while if it is an efficiency factor.
- Step 6: Construct a preference function Pj (Bi, Br) of the alternative Bi relative to Br under the attribute Gj using equation (14).

$$P_j(B_i, B_r) = \{0\ , d \leq p\ \frac{d-p}{q-p}\ , p < d < q\ 1\ , d \geq q \tag{19}$$

- Step 7: Calculate the relative weight of the attributes $w_{jr}$, which is the relative weight of Gj to Gr, where

$$w_{jr} = \frac{w_j}{w_r} = (j, r = 1,2, \dots, n) \tag{20}$$

- Step 8: Define the priority index π (Bi, Br) of the Bi scheme relative to Br by

$$\pi(B_i, B_r) = \frac{\sum_{j=1}^{n} w_{jr} P_j(B_i, B_r)}{\sum_{j=1}^{n} w_{jr}} \tag{21}$$

- Step 9: Calculate the inflow $+(Bi)$, the outflow $-(Bi)$, and the net flow $(Bi)$ as follows

$$^{+}(B_i) = \frac{\sum_{r=1}^{m} \pi(B_i, B_r) - \{\sum_{r=1}^{m} \pi(B_i, B_r)\}}{\{\sum_{r=1}^{m} \pi(B_i, B_r)\} - \{\sum_{r=1}^{m} \pi(B_i, B_r)\}} \tag{22}$$

$$^{-}(B_i) = \frac{\sum_{r=1}^{m} \pi(B_r, B_i) - \{\sum_{r=1}^{m} \pi(B_r, B_i)\}}{\{\sum_{r=1}^{m} \pi(B_r, B_i)\} - \{\sum_{r=1}^{m} \pi(B_r, B_i)\}} \tag{23}$$

$$(B_i) =^{+} (B_i) -^{-} (B_i) \tag{24}$$

- Step 10: Classify all the alternatives according to the value of $(B_i)$. The higher the value of $(B_i)$, the better the alternative.

## 4. Results of the application of the algorithm

The selection of the best alternative of 4 experimental cancer drugs for breast cancer treatment is taken as a case study. So the alternatives to be selected will be evaluated taking into account the criteria shown in figure 1:



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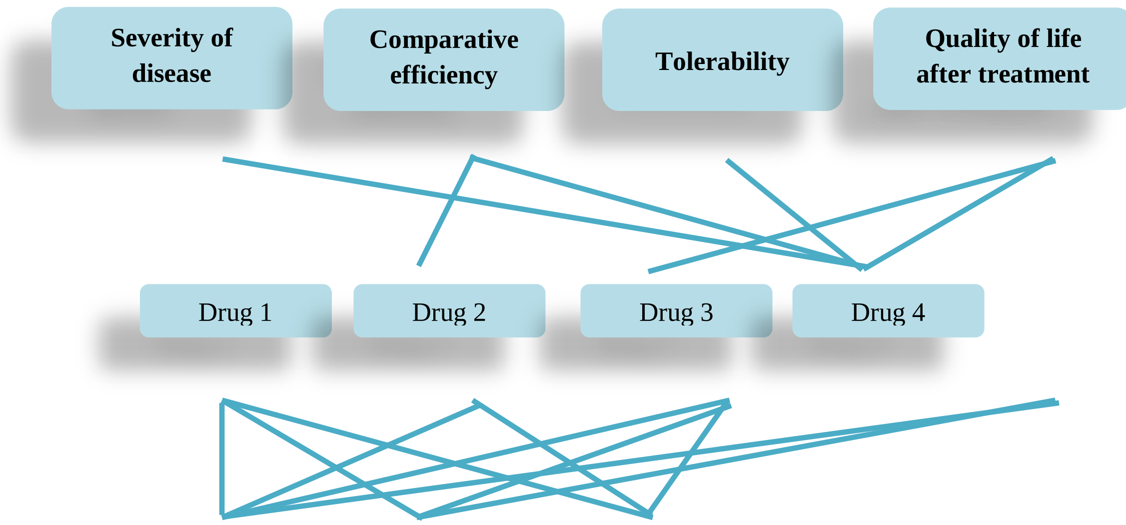


Figure 1: Relationship between alternatives and evaluation criteria. Source: Own elaboration

Decision-makers use the linguistic values shown in Table 1 to determine the performance of each alternative concerning each selected criterion. The weighting information provided to the four criteria by the five decision-makers is presented in Table 2.

Table 2: Weight matrix. Source: Own elaboration

| | | | | | |
|---|---|---|---|---|---|
| **C1. Comparative efficiency** | | | | | |
| | K1 | K2 | K3 | K4 | K5 |
| **Drug 1** | (0.9,0.1,0.1) | (0.35,0.75,0.80) | (0.35,0.75,0.80) | (0.10,0.90,0.90) | (0.9,0.1,0.1) |
| **Drug 2** | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.50,0.5,0.50) |
| **Drug 3** | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.9,0.1,0.1) |
| **Drug 4** | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.50,0.5,0.50) | (0.9,0.1,0.1) | (0.75,0.25,0.20) |
| **C2. Tolerability** | | | | | |
| | K1 | K2 | K3 | K4 | K5 |
| **Drug 1** | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) |
| **Drug 2** | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.9,0.1,0.1) |
| **Drug 3** | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.50,0.5,0.50) | (0.9,0.1,0.1) |
| **Drug 4** | (0.9,0.1,0.1) | (0.50,0.5,0.50) | (0.50,0.5,0.50) | (0.9,0.1,0.1) | (0.75,0.25,0.20) |
| **C3. Quality of life after treatment** | | | | | |
| | K1 | K2 | K3 | K4 | K5 |
| **Drug 1** | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.50,0.5,0.50) | (0.9,0.1,0.1) |
| **Drug 2** | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.75,0.25,0.20) |
| **Drug 3** | (0.50,0.5,0.50) | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.75,0.25,0.20) |
| **Drug 4** | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.50,0.5,0.50) | (0.75,0.25,0.20) | (0.9,0.1,0.1) |
| **C4. Severity of the disease** | | | | | |



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| | K1 | K2 | K3 | K4 | K5 |
|---|---|---|---|---|---|
| **Drug 1** | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.75,0.25,0.20) |
| **Drug 2** | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.9,0.1,0.1) | (0.75,0.25,0.20) | (0.9,0.1,0.1) |
| **Drug 3** | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) | (0.9,0.1,0.1) |
| **Drug 4** | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.75,0.25,0.20) | (0.75,0.25,0.20) |

For the analysis carried out, it is considered that all decision-makers have a very important evaluation (VI), according to the linguistic values provided in table 1, for an evaluation of 0.2. Starting from this, we proceed to determine the matrix of single values, shown in table 3, by using equation 4.

Table 3: Aggregate decision matrix. Source: Own elaboration

| Alternatives | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| **Drug 1** | (0.67189,0.34743,0.35652) | (0.9,0.1,0.1) | (0.86203,0.13797,0.13797) | (0.8557,0.1443,0.132) |
| **Drug 2** | (0.83428,0.16572,0.15849) | (0.85573,0.14427,0.13195) | (0.85573,0.14427,0.13195) | (0.8267,0.1733,0.1516) |
| **Drug 3** | (0.85573,0.14427,0.13195) | (0.80095,0.19905,0.18206) | (0.76091,0.23909,0.20913) | (0.9,0.1,0.1) |
| **Drug 4** | (0.76091,0.23909,0.20913) | (0.77135,0.22865,0.21867) | (0.80095,0.19905,0.18206) | (0.75,0.25,0.2) |

The vector of weights of the criteria evaluated by the analysts is shown below. To apply the weights of the criteria obtained, we proceed to the de-neutrosophication of the weights obtained in the TOPSIS method, by applying Equation 11.

Table 4: Vector of weights of the criteria. Own elaboration

| Criterion | Criteria weights (TOPSIS method) | Criteria Weights (PROMETHEE Modification) |
|---|---|---|
| **C1** | (0.9; 0.1; 0.1) | 0.9 |
| **C2** | (0.76091; 0.23909; 0.20913) | 0.7705 |
| **C3** | (0.87989; 0.12011; 0.11487) | 0.8816 |
| **C4** | (0.67012; 0.32988; 0.28854) | 0.6833 |

After performing the computation indicated by the logic of each method, the results shown in tables 5 and 6 are obtained.

Table 5: Positive and negative ideal values and distances of the TOPSIS method. Source: Own elaboration

| Alternatives | Ideal value + | Ideal value - | d + | d- | CP | Preference order |
|---|---|---|---|---|---|---|
| **Drug 1** | (0.77016; 0.22984; 0.21876) | (0.6047; 0.41269; 0.42087) | 0.1861 | 0.1416 | 0.43204 | 3 |
| **Drug 2** | (0.68482; 0.31518; 0.28822) | (0.58693; 0.41307; 0.38207) | 0.0591 | 0.1982 | 0.77025 | 1 |
| **Drug 3** | (0.75849; 0.24151; 0.23699) | (0.66952; 0.33048; 0.29998) | 0.1086 | 0.2072 | 0.65613 | 2 |
| **Drug 4** | (0.60311; 0.39689; 0.35969) | (0.50259; 0.49741; 0.43083) | 0.1632 | 0.1104 | 0.40352 | 4 |

Table 6: Input, output, and net flows of the alternatives as modified by PROMETHEE. Source: Own elaboration

| Alternatives | □□ | □□ | □ | Preference order |
|---|---|---|---|---|
| **Drug 1** | 0.516 | 1,000 | -0.484 | 3 |
| **Drug 2** | 1 | 0.000 | 1,000 | 1 |



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| | | | | |
|---|---|---|---|---|
| **Drug 3** | 0.905 | 0.322 | 0.584 | 2 |
| **Drug 4** | 0 | 0.879 | -0.879 | 4 |

As can be seen in table 5, the TOPSIS method shows that drug 2 has a closer approximation to the positive ideal value, followed by drug 3. In this case, both treatments have evaluations very similar to each other. The drug that is closest to the ideal value is drug 4.

In the case of the modified PROMETHEE method, the same results as with the TOPSIS method are observed. This method offers results relative to the level of preference of an alternative concerning the others and also offers information about the degree of non-preference of an alternative with respect to the others. In this method, a significant difference is observed between the total preferences of drug 2 with respect to 3, although this difference is given because drug 3 has a higher level of negative flow.

On the other hand, although the net flow of drug 4 is the lowest, the negative flow of drug 1 is the one with the highest level of non-preference with respect to the other alternatives. Regarding the information obtained from both methods, it can be concluded that both methods coincided in terms of the preferred results of the medical technology to be analyzed.

## 5. Conclusions

Multicriteria decision methods are powerful tools in the hands of those who know how to take advantage of the facilities they provide to solve all kinds of complex problems. The health field, being one of the most important for the preservation of the human being, must take more strongly the benefits that it offers and integrate the application of these tools into the resolution of its daily problems.

The study carried out allowed the application and comparison of the results obtained from the application of two multicriteria decision methods, relying on the contributions made by neutrosophy. Linguistic variables were used to facilitate the evaluation of the criteria and alternatives so that it was easier for the analysts to handle the information. The evaluations carried out were computed by using single value neutrosophic numbers.

The results showed that both methods coincided in the order of preference given to each treatment. However, it is observed that the method based on PROMETHEE yields more detailed information on the interiorities of the elections made. The effectiveness of the methods used can be verified and their practical and feasible application in complex medical problems.

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