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Research Article

A Novel Multicriteria Decision-Making Method Based on Distance, Similarity, and Correlation: DSC TOPSIS

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Decision-making, briefly defined as choosing the best among the possible alternatives within the possibilities and conditions available, is a far more comprehensive process than instant. While in the decision-making process, there are often a lot of criteria as well as alternatives. In this case, methods referred to as Multicriteria Decision-Making (MCDM) are applied. The main purpose of the methods is to facilitate the decision-maker's job, to guide the decision-maker and help him to make the right decisions if there are too many options. In cases where there are many criteria, effective and useful decisions have been taken for granted at the beginning of the 1960s for the first time and supported by day-to-day work. A variety of methods have been developed for this purpose. The basis of some of these methods is based on distance measures. The most known method in the literature based on the concept of distance is, of course, a method called Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In this study, a new MCDM method that uses distance, similarity, and correlation measures has been proposed. This new method is shortly called DSC TOPSIS to include the initials of distance, similarity, and correlation words, respectively, prefix of TOPSIS name. In the method, Euclidean was used as distance measure, cosine was used as similarity measure, and Pearson correlation was used as relation measure. Using the positive ideal and negative-ideal values obtained from these measures, respectively, a common positive ideal value and a common negative-ideal value were obtained. Afterward DSC TOPSIS is discussed in terms of standardization and weighting. The study also proposed three different new ranking indexes from the ranking index used in the traditional TOPSIS method. The proposed method has been tested on the variables showing the development levels of the countries that have a very important place today. The results obtained were compared with the Human Development Index (HDI) value developed by the United Nations.

1. Introduction

Decision-making with the simplest definition is the process of making choices from the available alternatives. Although it was expressed in different forms, basically a decision-making process involves: identification of the objective, selection of the criteria, selection of the alternatives, selection of the weighting methods, determination of aggregation method, and making decisions according to the results.

To be able to adapt to rapidly changing environmental conditions and make effective decisions in parallel with this change can only be possible by using scientific methods that can evaluate a large number of qualitative and quantitative factors in the decision-making process [1]. Many problems encountered in real life fit the definition of multicriteria decision-making. People find their individual preferences while they are present in evaluative judgments in multicriteria decision-making problems. It may not be difficult to decide when there are few criteria or few alternatives. However, as the subject becomes more complex, the information processing capacity of people is restricted, decision-making becomes more difficult, and help may be needed. In such cases, instead of trying to integrate too much knowledge and trying to decide, applying simple rules and procedures and evaluating the problem gradually will make it easier to decide. Such approaches will also facilitate decision-makers to make

rational decisions, and the decision will be appropriate within the constraints [1].

Taking more than one criterion, choosing the most appropriate one among the alternatives, or alternating sorting problems is called Multicriteria Decision-Making (MCDM) problems. The MCDM could have been appropriate for the purposes of evaluating the alternatives in a particular order, or alternatively, in order to determine the alternatives [2]. MCDM methods, which are used in a wide range of fields from personal selection problems to economic, industrial, financial, political decision problems, have begun to develop together with the increasingly complex decision-making process from the beginning of 1960's. In particular, MCDM methods are being used to control the decision-making mechanism and to obtain the decision result as quickly and as easily as possible, provided that the target to be achieved is explained by a number of criteria and each of the alternatives has its own advantages. MCDM methods can involve different decision-makers in the decision-making process and allow many factors related to the decision-making problem to be evaluated simultaneously at different levels [1].

TOPSIS, one of the MCDM methods, developed by Hwang and Yoon [3] is a technique to evaluate the performance of alternatives through the similarity with the ideal solution. According to this technique, the best alternative would be one that is closest to the positive-ideal solution and farthest from the negative-ideal solution. The positive-ideal solution is one that maximizes the benefit criteria and minimizes the cost criteria. The negative-ideal solution maximizes the cost criteria and minimizes the benefit criteria. In summary, the positive-ideal solution is composed of all best values attainable of criteria, and the negative-ideal solution consists of all the worst values attainable of criteria [4–6].

The basis of this study is based on the report presented in the statistics conference (istkon 2017) held in Turkey in 2017 [7]. In the report, it was emphasized that TOPSIS method could be formed in different structures by drawing attention to the unit of measurement. In addition, it was noted that ranking indexes may also be different. This study was carried out with the consideration of the issues discussed in the congress and much more.

In this study, a new MCDM method based on the traditional TOPSIS method is proposed. In the proposed method, ideal positive solution approximation or ideal negative solution distance is calculated based on the distance, similarity, and correlation (DSC) measures, unlike the traditional TOPSIS method. For this reason, this new unit of measure proposed to rank alternatives is named as DSC and the new MCDM method developed is called DSC TOPSIS. The main advantage of the proposed unit of measurement is that it does not only rank the alternatives according to the concept of distance but also according to the concepts of similarity and correlation. In other words, the major advantage of the proposed method is that it proposes a stronger unit of measure by considering the three basic concepts that can be used to compare units: distance, similarity, and correlation. Another advantage of the proposed new MCDM method is that it suggests three new different methods that can be used to rank alternatives according to their importance levels. In addition, the impact of the proposed method on the cases where the decision matrix is dealt with by row, column, and double standardization methods is discussed in detail. These methods are applied to the results obtained by the proposed method. Thus, the traditional TOPSIS method and the sorting technique used in this method are compared with the proposed MCDM method and the proposed three new sorting methods. The functioning of the method has been tested to determine the order of development of countries. For this purpose, the indicators of Human Development Index (HDI) calculated by UN Development Programme (UNDP) have been utilized. The results were compared with HDI and traditional TOPSIS values.

There are no studies in the literature that use the concepts of distance, similarity, and correlation together. In this context, this study will be the first. The closest one to the proposed method in this study is Deng's method which was published in the study entitled "A Similarity-Based Approach to Ranking Multicriteria" in 2007. With this study Deng presented a similarity-based approach to ranking multicriteria alternatives for solving discrete multicriteria problems. Then Safari and et al. [5] modified Deng's similarity-based method and they proposed a new MCDM method based on similarity and TOPSIS. And then Safari and Ebrahimi [8] used a similarity-based technique by Deng [4] to rank countries in terms of HDI. They also proposed a solution for resolving a problem which exists in Deng's method. Although the issue discussed in the application part of Safari and Ebrahimi [8] and this study is on HDI data, the ways of handling this data are different. The most important difference between the two studies is the selection of criteria. While Safari and Ebrahimi [8] preferred to use "life expectancy at birth," "mean years of schooling, "expected years of schooling," and "log GNI," which are the indicator of HDI, as criteria, in this study, it was preferred to use "Life," "Education," and "Income" indexes that expressed the dimensions of HDI. At this point, Safari and Ebrahimi's [8] method can be criticized on their preferred criteria. That is, HDI's two indicators of the education dimension are considered as separate criteria in their study; in fact, it gave more weight to the dimension of education than the other dimensions in terms of relative importance. In this context, with this study, a suggestion has been made to this situation mentioned above. Another difference is undoubtedly that the HDI data discussed in both studies are of different years.

In the following sections, the concepts of distance, similarity, and correlation will be mentioned first (Section 2). Then, in Section 3, respectively, the operation of the traditional TOPSIS method will be described; the steps of the MCDM method proposed in the study will be given; and the proposed sorting methods will be explained. In Section 4; the functioning of the proposed MCDM method and ranking techniques will be tested on the variables that indicate the level of development of the countries. For this purpose, brief information about HDI will be given first in this section. In Section 5 evaluation of the results obtained will be made.

2. Distance, Similarity, and Correlation

Since the new unit of measurement proposed in the study, which is developed as an alternative to the unit of measurement used in the traditional TOPSIS method, is based on the concepts of distance, similarity, and correlation, these and related concepts will be briefly explained in the following subsections. Thus, a better understanding of the proposed unit of measurement will be provided.

2.1. Metrics, the Euclidean Distance. Any function d_{ij} is defined as a metric in case it satisfies the following four conditions (metric axioms) for all points [9–11].

(i) If $i = j$ then $d_{ij} = 0$,

(ii) If $i \neq j$, then $d_{ij} > 0$,

(iii) $d_{ij} = d_{ji}$ (*symmetry axiom*),

(iv) $d_{ij} + d_{ik} \geq d_{jk}$ for any triple i, j, k of points (*triangle inequality axiom*),

In mathematics, distance and metric expressions are used in the same sense [12]. The most important and special case of a family of functions, metrics, or distances is known as Euclidian distance. Euclidean distance is defined as the linear distance between two points in the simplest sense.

2.2. Dissimilarity. Any function d_{ij} is defined as "dissimilarity" if the first three of the metric axioms described above are satisfied. Thus, dissimilarity is more general concept. The upper and lower bound of the most dissimilarity functions are 1 and 0, respectively ($0 \leq d_{ij} \leq 1$).

2.3. Similarity. The most common measure used to compare two cases is similarity. The most important reason why similarity is more preferable than distance and dissimilarity is that it is easier for people to find similar aspects when comparing two things. Similar to dissimilarity, the concept of similarity varies between 0 and 1 ($0 \leq s_{ij} \leq 1$). Similarity is the complement of the dissimilarity. This relationship between the two concepts is shown in

$$s_{ij} = 1 - d_{ij} \tag{1}$$

There are a variety of transforms methods for achieving a distance from similarity. Including transformation given in (2), the most preferred ones are $d_{ij} = 1 - s_{ij}$, $d_{ij} = \sqrt{1 - s_{ij}}$, $d_{ij} = (1 - s_{ij})/s_{ij}$, $d_{ij} = \sqrt{2(1 - s_{ij}^2)}$, $d_{ij} = \arccos s_{ij}$, $d_{ij} = -\ln s_{ij}$, etc. [11].

The transformation given in (2) contains special meaning. That is, if many coefficients are converted according to this formula in the range of $[0, 1]$, the structure to be obtained will be a metric or even Euclidean [10].

$$d_{ij} = \sqrt{1 - s_{ij}} \tag{2}$$

2.4. Correlation and Association. The concepts of distance, dissimilarity, and similarity can be interpreted in geometrical terms because they express the relative positions of points in multidimensional space. On the other hand, the association and correlation concepts reveal the relations between the axes of the same space based on the coordinates of the points.

Except for covariance, most of association and correlation coefficients measure the strength of the relationship in the interval of $[-1, 1]$. These coefficients can be easily converted to Euclidean by using (2) [10].

2.5. Some Distances and Similarities. The *power* (p, r) *distance* is a distance on $\mathfrak{R}^n$ defined by

$$\left(\sum_i^m |x_i - y_i|^p\right)^{1/r} \tag{3}$$

For $p = r \geq 1$, it is the l_p-*metric*, including the *Euclidean, Manhattan* (or magnitude or city block), and *Chebyshev* (or maximum value, dominance) *metrics* for $p = 2$, 1 and ∞, respectively. The case $(p, r) = (2, 1)$ corresponds to the *squared Euclidean distance* [11].

The *covariance similarity* is a similarity on $\mathfrak{R}^n$, defined by

$$\text{cov\_}s_{ij} = \frac{\sum_i^m (x_i - \overline{x})(y_i - \overline{y})}{n} = \frac{\sum_i^m x_i y_i}{n} - \overline{x}.\overline{y} \tag{4}$$

The *correlation similarity,* which is also referred to as Pearson correlation or Pearson product-moment correlation linear coefficient, is a similarity on $\mathfrak{R}^n$, defined by

$$corr\_s_{ij} = \frac{\sum_i^m (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\left(\sum_i^m (x_i - \overline{x})^2\right)\left(\sum_i^m (y_i - \overline{y})^2\right)}} \tag{5}$$

The *dissimilarities*

$$1 - \left(corr\_s_{ij}\right) \tag{6}$$

$$1 - \left(corr\_s_{ij}\right)^2 \tag{7}$$

are called the *Pearson correlation distance and squared Pearson distance*, respectively.

The *cosine similarity* (or Orchini similarity, angular similarity, normalized dot product) is a similarity on $\mathfrak{R}^n$, defined by

$$\cos\_s_{ij} = \frac{\sum_i^m (x_i - y_i)^2}{\sqrt{\left(\sum_i^m (x_i)^2\right)\left(\sum_i^m (y_i)^2\right)}} = \frac{\langle x, y\rangle}{\|x\|_2 . \|y\|_2} = \cos\phi \tag{8}$$

were ϕ is the angle between vectors x and y.

According to this, the *cosine dissimilarity or cosine distance* are defined by

$$1 - \left(\cos\_s_{ij}\right) \tag{9}$$

2.6. Global Distance. The "global distance" is a measure in which the result of combining the various distance measures is called "local distance" with different methods. The most common of these methods used to combine local distances are "total sum, weighted sum, and weighted average (e.g., geometric mean)" [13].

3. Multicriteria Decision-Making

MCDM problem is a problem in which the decision-maker intends to choose one out of several alternatives on the basis of a set of criteria. MCDM constitutes a set of techniques which can be used for comparing and evaluating the alternatives in terms of a number of qualitative and/or quantitative criteria with different measurement units for the purpose of selecting or ranking [8].

MCDM problems are divided into Multiattribute Decision-Making (MADM) and Multiobjective Decision-Making (MODM) problems. The MADM problems have a predetermined number of alternatives and the aim is to determine the success levels of each of these alternatives. Decisions in the MADM problems are made by comparing the qualities that exist for each alternative. On the other hand, in the MODM problems, the number of alternatives cannot be determined in advance and the aim of the model is to determine the "best" alternative [14]. There are different methods used in the literature for the solution of MCDM problems [15–17] and none of these methods gives a complete advantage over others. The most important advantage of these methods is that they allow us to evaluate quantitative and qualitative criteria together. The most well-known MCDM methods are Weighted Sum Method (WSM), Weighted Product Method (WPM), Analytic Network Process (ANP) method, Analytical Hierarchy Process (AHP) method, ELimination Et Choix Traduisant la REalité (ELECTRE), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Superiority and Inferiority Ranking (SIR), and so on.

Regardless of the type of decision-making problem, the decision-making process generally consists of the following four basic steps:

(i) determination of criteria and alternatives,

(ii) assignment of numerical measures of relative importance to criteria,

(iii) assigning numerical measures to alternatives according to each criterion,

(iv) numerical values for sorting alternatives.

The MCDM methods have been developed to effectively carry out the fourth stage of this process. There are different methods used in the literature for the solution of MCDM problems. The differences between the methods are due to the approaches that they recommend to make decisions. *In fact, no one has a complete superiority over the other*.

In this study, a new MCDM method based on the traditional TOPSIS method is proposed. In the proposed method, ideal positive solution approximation or ideal negative solution distance is calculated based on the distance, similarity, and correlation measures, unlike the traditional TOPSIS method. For this reason, the method is called DSC TOPSIS. Three different new methods are also proposed in order to rank the alternatives according to their importance levels in DSC TOPSIS or similar MCDM methods. There are several studies in the literature that modify the TOPSIS method. Some of them can be listed as follows. Hepu Deng [4], in his paper named as "*A Similarity-Based Approach to Ranking Multi-Criteria Alternatives*" presented a similarity-based approach to ranking multicriteria alternatives for solving discrete multicriteria problems. Ren and et al. [18] introduced a novel modified synthetic evaluation method based on the concept of original TOPSIS and calculated the distance between the alternatives and "optimized ideal reference point" in the D^+ D^- plane and constructing the P value to evaluate quality of alternative in their study titled "*Comparative Analysis of a Novel M-TOPSIS Method and TOPSIS*." Cha [19] built the edifice of distance/similarity measures by enumerating and categorizing a large variety of distance/similarity measures for comparing nominal type histograms at the paper titled "*Comprehensive Survey on Distance/Similarity Measures between Probability Density Functions*." Chakraborty S. and Yeh C.-H. [20], in the study named as "*A Simulation Comparison of Normalization Procedures for TOPSIS*," compare four commonly known normalization procedures in terms of their ranking consistency and weight sensitivity when used with TOPSIS to solve the general MADM problem with various decision settings. Chang et al. [21] adopted the concepts of "Ideal" and "Anti-Ideal" solutions as suggested by Hwang and Yoon [3] and studied the extended TOPSIS method using two different "distance" ideas, namely, "Minkowski's L_λ metric" and "Mahalanobis" distances in their study titled "*Domestic Open-End Equity Mutual Fund Performance Evaluation Using Extended Topsis Method with Different Distance Approaches*." Hossein and et al. [5] in their paper named as "*A New Technique for Multi Criteria Decision-Making Based on Modified Similarity Method*" modified Deng's similarity-based method. Omosigho and Omorogbe [22] in their study named as "*Supplier Selection Using Different Metric Functions*" examined the deficiencies of using only one metric function in TOPSIS and proposed the use of spherical metric function in addition to the commonly used metric functions. Kuo [23] in his paper named as "*A Modified TOPSIS with a Different Ranking Index*" by proposing w^- and w^+ as the weights of the "*cost*" criterion and the "*benefit*" criterion, respectively, he defined a new *ranking index*.

Since the proposed method is based on the TOPSIS method, the steps of the traditional TOPSIS method will first be explained in the following subsections. And then the details of the proposed MCDM method will be discussed.

3.1. TOPSIS Method

Step 1. Determining the decision matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & x_{ij} & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{10}$$

In a decision matrix, lines represent alternatives A_i $(i = 1, 2, \ldots, n)$ and columns refer to criteria C_j $(j = 1, 2, \ldots, m)$.

Step 2. Determining the weighting vector as follows:

$$W = \left(w_1, \cdots, w_j, \cdots, w_m\right) \tag{11}$$

in which the relative importance of criterion C_j with respect to the overall objective of the problem is represented as w_j.

Step 3. Normalizing the decision matrix through Euclidean normalization:

$$x'_{ij} = \frac{x_{ij}}{\left(\sum_{j=1}^{n} x_{ij}^2\right)^{1/2}} \tag{12}$$

As a result, a normalized decision matrix can be determined as

$$X' = \begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1m} \\ x'_{21} & x'_{22} & \cdots & x'_{2m} \\ \cdots & \cdots & x'_{ij} & \cdots \\ x'_{n1} & x'_{n2} & \cdots & x'_{nm} \end{bmatrix} \tag{13}$$

Step 4. Calculating the performance matrix:

The weighted performance matrix which reflects the performance of each alternative with respect to each criterion is determined by multiplying the normalized decision matrix (13) by the weight vector (11).

$$\begin{aligned} Y &= \begin{bmatrix} w_1 x'_{11} & w_2 x'_{12} & \cdots & w_m x'_{1m} \\ w_1 x'_{21} & w_2 x'_{22} & \cdots & w_m x'_{2m} \\ \cdots & \cdots & w_i x'_{ij} & \cdots \\ w_1 x'_{n1} & w_2 x'_{n2} & \cdots & w_m x'_{nm} \end{bmatrix} \\ &= \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1m} \\ y_{21} & y_{22} & \cdots & y_{2m} \\ \cdots & \cdots & y_{ij} & \cdots \\ y_{n1} & y_{n2} & \cdots & y_{nm} \end{bmatrix} \end{aligned} \tag{14}$$

Step 5. Determining the PIS and the NIS:

The positive-ideal solution (PIS) and the negative-ideal solution (NIS) consist of the best or worst criteria values attainable from all the alternatives. Deng [4] enumerated the advantages of using these two concepts as: their simplicity and comprehensibility, their computational efficiency, and their ability to measure the relative performance of the alternatives in a simple mathematical form [8].

For PIS (I^+),

$$I^+ = \left\{\left(\max_i y_{ij} \mid j \in J\right), \left(\min_i y_{ij} \mid j \in J'\right\}\right. \tag{15}$$

$$I^+ = \{I_1^+, I_2^+, \ldots, I_n^+\} \tag{16}$$

And for NIS (I^-),

$$I^- = \left\{\left(\min_i y_{ij} \mid j \in J\right), \left(\max_i y_{ij} \mid j \in J'\right\}\right. \tag{17}$$

$$I^- = \{I_1^-, I_2^-, \ldots, I_n^-\} \tag{18}$$

At both formulas, J shows benefit (maximization) and J' shows loss (minimization) value.

Step 6. Calculating the degree of distance of the alternatives between each alternative and the PIS and the NIS:

The D^+ and the D^- formulas are given in (19) and (20), respectively, by using Euclidean distance.

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(y_{ij} - I_j^+\right)^2} \tag{19}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(y_{ij} - I_j^-\right)^2} \tag{20}$$

Step 7. Calculating the overall performance index for each alternative across all criteria:

$$P_i^1 = \frac{D_i^-}{D_i^- + D_i^+} \tag{21}$$

$0 \le P_i \le 1$. The P_i value indicates the absolute closeness of the ideal solution. If $P_i = 1$ then A_i is the PIS; if $P_i = 0$ then A_i is the NIS.

Step 8. Ranking the alternatives in the descending order of the performance index value.

3.2. Proposed Method. The approaches used in the steps of "normalizing the decision matrix," "calculating the distance of positive and negative-ideal solutions," and "calculating the overall performance index for each alternative across all criteria" of the traditional TOPSIS method are open to interpretation and can be examined, improved, or modified. Approaches that can be recommended in these steps are briefly summarized below.

"Normalizing the decision matrix" step (Step 3 at the traditional TOPSIS): The normalization method used to normalize the decision matrix can also be achieved with different normalization formulas. Also, for this step, standardization rather than normalization is one of the methods that can be applied.

"Calculating the distance of positive- and negative-ideal solutions" step (Step 6 at the traditional TOPSIS): alternative to the distance of Euclidean (Minkowski L_2), which is used to calculate the distance of PIS and NIS, is also possible to use many different distance measures such as linear [15], spherical [22], Hamming [22], Chebyshev [21], Dice [24], Jaccard [24], and cosine (Liao and Xu, 2015). The concept of similarity is also considered as an alternative (Zhongliang, 2011 and [4]).

"Calculating the overall performance index for each alternative across all criteria" step (Step 7 at the traditional TOPSIS): different approaches such as the concept of distance can be used instead of the simple ratio recommended in the traditional TOPSIS method since it is considered to be a very simple way by most researchers.

To offer solutions to the weaknesses listed above, in this study instead of

(i) "normalization approach" applied in Step 3 of the traditional TOPSIS method, *column and row-standardization approach*,

(ii) "euclidean distance" used in Step 6, *a new measure based on the concept of "distance, similarity and correlation" (DSC)*,

(iii) "simple ratio" used in Step 7, *new sorting approaches based on the concept of distance* have been proposed.

This method, which could be an alternative to MCDM methods especially TOPSIS, due to the new measure proposed is called DSC TOPSIS. The main objective of

(i) using different standardization methods is to emphasize what can be done for different situations that can be encountered in real life problems;

(ii) developing a new measure for the traditional TOPSIS method in this study is to improve the approach of "evaluating the two alternatives only based on the Euclidean distance to the PIS and NIS values" and make it more valid;

(iii) developing new sorting methods is to criticize the method used in traditional TOPSIS because it is based on simple rate calculation.

At this point, an important issue mentioned earlier must be remembered again. That is, the fact that none of the MCDM methods is superior to the other. Therefore, the new MCDM method proposed in this study will certainly not provide a full advantage over other methods. But a different method will be given to the literature.

Basically, there are three approaches used to compare vectors. These are distance, similarity, and correlation. The concept of distance is the oldest known comparison approach and is the basis of many sorting or clustering algorithms. On the other hand both similarity and correlation are two other important concepts that should be used in vector comparisons. According to Deng [4] mathematically, comparing two alternatives in the form of two vectors is better represented by the magnitude of the alternatives and the degree of conflict between each alternative and the ideal solution, rather than just calculating the relative distance between them [8]. The degree of conflict between each alternative and the ideal solution is calculated by "cosine similarity." On the other hand, it is possible to compare alternatives according to their relationship. In this case, the concept of correlation that evaluates from another point of view and therefore correlation similarity will be introduced. Briefly Euclidean distance, cosine similarity, and correlation similarity arise as the basic metrics that can be used for ranking the alternatives.

In order to express an MCDM problem in "m-dimensional real space," alternatives can be represented by A_i vector and PIS and NIS can be represented by I_j^+ and I_j^- vectors, respectively. In this case, the angle between A_i and I_j^+ (I_j^-) in the m-dimensional real space, which is shown by θ_i^+ (θ_i^-), is a good measure of conflict between the vectors [8]. These vectors (I_j^+, I_j^-) and the degree of conflict ($\cos\theta_i$) between them are shown in Figure 1 by Deng [4].

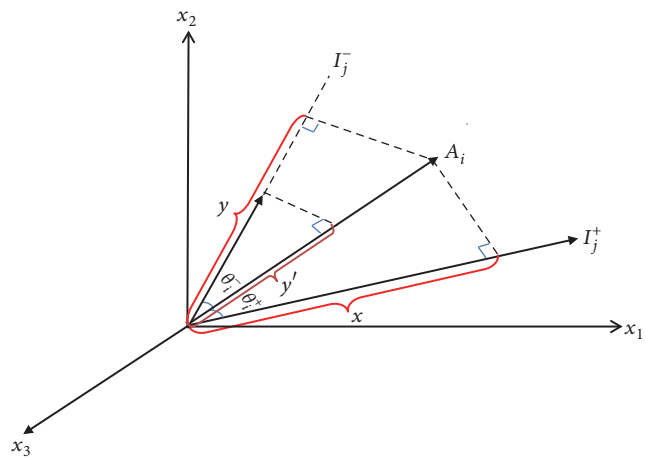

Figure 1: The degree of conflict.

The situation of conflict occurs when $\theta_i \neq 0$, that is, when the gradients of A_i and I_j^+ (I_j^-) are not coincident. Thus the conflict index is equal to "one" as the corresponding gradient vectors lie in the same direction, and the conflict index is "zero" when $\theta_i = \pi/2$ which indicates that their gradient vectors have the perpendicular relationship with each other [4, 8].

In the light of the above-mentioned explanations and causes, the three approaches of "*distance, similarity, and correlation*" that can be used to compare vectors have been exploited in order to combine them in a common pavilion to develop a stronger comparison measure. Thus, the steps detailed below have been carried out.

3.2.1. Proposed Step 3: Standardize the Decision Matrix. Unlike the traditional TOPSIS method, this step has been developed on the basis of standardization. The differences of column and row-standardization were emphasized.

Standardization vs. Normalization. Data preprocessing, which is one of the stages of data analysis, is a very important process. One of the first steps of data preprocessing is the normalization of data. This step is particularly important when working with variables that contain different units and scales.

All parameters should have the same scale for a fair comparison between them when using the Euclidean distance and similar methods. Two methods are usually well known for rescaling data. These are "normalization" and "standardization." *Normalization* is a technique which scales all numeric variables in the range [0, 1]. In addition to (12) some other possible formulas of normalization are given below and the other is given in (59):

$$x'_{ij} = \frac{x_{ij}}{median_X} \tag{22}$$

$$x'_{ij} = \frac{x_{ij}}{\max\left(x_{ij}\right)} \tag{23}$$

On the other hand *standardization* is a method which transforms the variables to have zero mean and unit variance, for example, using the equation below:

$$x'_{ij} = \frac{x_{ij} - \mu_X}{\sigma_X} \tag{24}$$

Both of these techniques have their drawbacks. If you have outliers in your data set, normalizing your data will certainly scale the "normal" data to a very small interval. And generally, most of data sets have outliers. Furthermore these techniques can have negative effects. For example, if the data set dealt with outlier values, the normalization of this data will cause the data to be scaled at much smaller intervals. On the other hand using standardization is not bounded data set (unlike normalization). Therefore, in this study standardization method was preferred to use.

Standardization can be performed in three ways: *column-standardization* (variable or criteria), *row-standardization* (observation or alternative), and *double standardization* (both row and column standardization) [25]. In *column-standardization* variables are taken separately and observations for each variable are taken as a common measure, whereas in *row-standardization* the opposite is the case. That is, the observations are handled one by one and the variables are brought to the same measurement for each observation. In addition, it may be the case that both column-standardization and row-standardization are done together. This is referred to as "*double-standardization*."

Selection Appropriate Standardization Method. Different transformations of the data allow the researchers to examine different aspects of the underlying, basic structure. Structure may examine "wholistically" with main effects, interaction, and error present or the main effects can be "removed" to examine interaction (and error) [25].

A row or column effect can be removed with a transformation that sets row or column means (totals) to equal values. Centering or standardization of row or column variables results in a partial removal of the main effects, by setting one set of means to zero. Double centering and double standardization remove both sets of means. Removal of the "magnitude" or "popularity" dimension allows the researcher to examine the data for patterns of "interactive" structure [25].

Centering or standardization within rows removes differences in row means but allows differences in column mean to remain. Thus the "consensus" pattern among rows, characterized by differences in the column means, remains relatively unaffected. Column-standardization also removes only one set of means; column means are set to zero. Centering of data, usually performed on column or row variables, is analogous to analyzing a covariance matrix. Data are sometimes double-centered to remove the magnitude or popularity dimension (Green, 1973).

These are approaches that can be used in sorting and clustering alternatives. According to the structure of the decision problem, it is necessary to determine which standardization method should be applied. That is,

(i) *column standardization:* if observations are important,

(ii) *row-standardization:* if it is important to bring the variables to the same unit,

(iii) *double standardization:* where both observations and variables are important to be independent of the unit preferable.

3.2.2. Proposed Step 6: Calculating the Degree of Distance of the Alternatives between Each Alternative and the PIS and the NIS. In the context described above and in Section 2.5 (using geometric mean approach to combine local distances) the proposed new measure formula is constructed as follows.

$$\text{Pr}oposed\_d_i = \sqrt[3]{(squared\_d_i) \,.\, (corr\_d_i) \,.\, (\cos\_d_i)} \tag{25}$$

The three terms in the formula are "*the squared Euclidean distance* ((3), the case $(p, r) = (2, 1)$)," "*the correlation distance* (6)," and "*the cosine distance* (9)," respectively.

As mentioned before, the methods that can be used to determine the differences between vectors are distance, correlation, and similarity. In (25), these concepts were combined with the geometric mean and a stronger measure than the traditional TOPSIS method used to determine the differences between the vectors.

Below column-standardization and row-standardization cases of this proposed measure were discussed, respectively. In the literature, the effects of row-standardization on the TOPSIS method have not been addressed at all. For this reason, the effects of row-standardization on the TOPSIS method in this study were also investigated.

For Column-Standardization. In the case of standardizing the data according to the columns, in other words according to the alternatives, there is no change or reduction in the formulas of the squared Euclidean, correlation, and cosine distances used in the proposed measure. For this reason (25) can be used exactly in the case of column-standardization.

Thus, the degree of distance of the alternatives between each alternative and the PIS and the NIS for column-standardized data are as follows:

$$\begin{aligned} &\text{Pr}oposed\_D_i^+ \\ &\quad = \sqrt[3]{(squared\_d_i^+) \,.\, (corr\_d_i^+) \,.\, (\cos\_d_i^+)} \end{aligned} \tag{26}$$

$$\begin{aligned} &\text{Pr}oposed\_D_i^- \\ &\quad = \sqrt[3]{(squared\_d_i^-) \,.\, (corr\_d_i^-) \,.\, (\cos\_d_i^-)} \end{aligned} \tag{27}$$

For square Euclidean distance, cosine distance, and correlation distance, the D^+ and D^- values and, for correlation

similarity and cosine similarity, the S^+ and S^- values are, respectively, as follows.

Square Euclidean (Sq_Euc) Distance for Column-Standardized Data:

$$D_i^+ = \sum_{j=1}^{n} \left(y_{ij} - I_j^+\right)^2 \tag{28}$$

$$D_i^- = \sum_{j=1}^{n} \left(y_{ij} - I_j^-\right)^2 \tag{29}$$

Correlation Similarity (Corr_s) for Column-Standardized Data:

$$S_i^+ = \frac{\sum_j^m \left(y_j - \overline{y}\right)\left(I_j^+ - \overline{I}_j^+\right)}{\sqrt{\left(\sum_j^m \left(y_j - \overline{y}\right)^2\right)\left(\sum_j^m \left(I_j^+ - \overline{I}_j^+\right)^2\right)}} \tag{30}$$

$$S_i^- = \frac{\sum_j^m \left(y_j - \overline{y}\right)\left(I_j^- - \overline{I}_j^-\right)}{\sqrt{\left(\sum_j^m \left(y_j - \overline{y}\right)^2\right)\left(\sum_j^m \left(I_j^- - \overline{I}_j^-\right)^2\right)}} \tag{31}$$

Cosine Similarity (Cos_s) for Column-Standardized Data:

$$S_i^+ = \frac{\sum_j^m \left(y_j - I_j^+\right)^2}{\sqrt{\left(\sum_j^m \left(y_j\right)^2\right)\left(\sum_j^m \left(I_j^+\right)^2\right)}} \tag{32}$$

$$S_i^- = \frac{\sum_j^m \left(y_j - I_j^-\right)^2}{\sqrt{\left(\sum_j^m \left(y_j\right)^2\right)\left(\sum_j^m \left(I_j^-\right)^2\right)}} \tag{33}$$

Correlation Distance (Cor_d) for Column-Standardized Data:

$$\begin{aligned} D_i^+ &= 1 - S_i^+ \\ &= 1 - \frac{\sum_j^m \left(y_j - \overline{y}\right)\left(I_j^+ - \overline{I}_j^+\right)}{\sqrt{\left(\sum_j^m \left(y_j - \overline{y}\right)^2\right)\left(\sum_j^m \left(I_j^+ - \overline{I}_j^+\right)^2\right)}} \end{aligned} \tag{34}$$

$$\begin{aligned} D_i^- &= 1 - S_i^- \\ &= 1 - \frac{\sum_j^m \left(y_j - \overline{y}\right)\left(I_j^- - \overline{I}_j^-\right)}{\sqrt{\left(\sum_j^m \left(y_j - \overline{y}\right)^2\right)\left(\sum_j^m \left(I_j^- - \overline{I}_j^-\right)^2\right)}} \end{aligned} \tag{35}$$

Cosine Distance (Cos_d) for Column-Standardized Data:

$$D_i^+ = 1 - S_i^+ = 1 - \frac{\sum_j^m \left(y_j - I_j^+\right)^2}{\sqrt{\left(\sum_j^m \left(y_j\right)^2\right)\left(\sum_j^m \left(I_j^+\right)^2\right)}} \tag{36}$$

$$D_i^- = 1 - S_i^- = 1 - \frac{\sum_j^m \left(y_j - I_j^-\right)^2}{\sqrt{\left(\sum_j^m \left(y_j\right)^2\right)\left(\sum_j^m \left(I_j^-\right)^2\right)}} \tag{37}$$

For Row-Standardization. If the vectors are standardized according to the rows, some reductions are concerned in the formula of the recommended measure. It is detailed below (in the following, it is expressed as *Case 4*).

Let X and Y be two vectors. When μ_X and μ_Y are the means of X and Y, respectively, and σ_X and σ_Y are the standard deviations of X and Y, the correlation between X and Y is defined as

$$corr\_s_{XY} = \frac{(1/n)\sum_j^n x_j y_j - \mu_X \mu_Y}{\sigma_X \sigma_Y} \tag{38}$$

The numerator of the equation is called the *covariance* of X and Y and is the difference between the mean of the product of X and Y subtracted from the product of the means. If X and Y *are row-standardized*, they will each have a mean of "*0*" and a standard deviation of "*1*," so the (38) reduces to

$$corr\_s_{XY}^* = \frac{1}{n}\sum_j^n x_j y_j \tag{39}$$

While Euclidean distance is the sum of the squared differences, correlation is basically the average product. From the Euclidean distance formula it can be seen that there is further relationship between them.

$$\begin{aligned} Euc\_d_i &= \sqrt{\sum_j^n \left(x_j - y_j\right)^2} \\ &= \sqrt{\sum_j^n x_j^2 + \sum_j^n y_j^2 - 2\sum_j^n x_j y_j} \end{aligned} \tag{40}$$

If X and Y are *standardized*, at (40) the sum of squares will be equal to n ($\sum_j^n x_j^2 = n$ and $\sum_j^n y_j^2 = n$). So (40) reduced to (42).

$$Euc\_d_i^* = \sqrt{n + n - 2\sum_j^n x_j y_j} \tag{41}$$

$$= \sqrt{2\left(n - \sum_j^n x_j y_j\right)} \tag{42}$$

In this case, if the square of the Euclidean distance is taken (the *square distance*) and some adjustments are made, (42) reduced to the formula for the correlation coefficient as follows:

$$d_i^{2*} = 2n\left(1 - corr\_s_i{}^*\right) \tag{43}$$

In this way, for *row-standardized* data, the correlation between X and Y can be written in terms of the squared distance between them:

$$corr\_s_i{}^* = 1 - \frac{d_i^{2*}}{2n} \tag{44}$$

And the *correlation distance* is as

$$corr\_d_i^* = 1 - corr\_s_i^* = \frac{d_i^{2*}}{2n} \tag{45}$$

On the other hand, in the case $\overline{x} = 0$ and $\overline{y} = 0$ the correlation similarity becomes $\langle x, y\rangle/(\|x\|_2.\|y\|_2)$ which is the formula of *cosine similarity*. So the formula of correlation distance is the formula of *cosine distance* at the same time.

$$\cos\_d_i^* = corr\_d_i^* = \frac{d_i^{2*}}{2n} \tag{46}$$

Considering the relationships described above for row-standardized data correlation and cosine similarities are transformed into square distance value. Thus, these three concepts used to measure the differences between the vectors are expressed in the same way. Thus, (25) is converted into the form given in

$$\text{Pr}oposed\_d_i = \sqrt[3]{d_i^2.\frac{d_i^2}{2n}.\frac{d_i^2}{2n}} \tag{47}$$

$$= \frac{1}{\sqrt[3]{4n^2}}.d_i^2 \tag{48}$$

So, calculating the degree of distance of the alternatives between each alternative and the PIS and the NIS for row-standardized data are as follows:

$$\text{Pr}oposed\_D_i^+ = \frac{1}{\sqrt[3]{4n^2}}.d_i^{+2} = \frac{1}{\sqrt[3]{4n^2}}.\sum_{j=1}^{n}\left(y_{ij} - I_j^+\right)^2 \tag{49}$$

$$\text{Pr}oposed\_D_i^- = \frac{1}{\sqrt[3]{4n^2}}.d_i^{-2} = \frac{1}{\sqrt[3]{4n^2}}.\sum_{j=1}^{n}\left(y_{ij} - I_j^-\right)^2 \tag{50}$$

In row-standardization case the D^+, D^- and S^+, S^- values for square Euclidean distance, correlation similarity, cosine similarity, correlation distance, and cosine distance are as follows. Differently here the reduced states of the correlation and cosine formulas are used (for column-standardization was explained at *Proposed Step 6*, with (30)-(37)). For this reason the correlation S^+ and S^- formulas are equal to the formulas of cosine S^+ and S^-, respectively.

Square Euclidean (Sq_Euc) Distance for Row-Standardized Data. The D^+ and D^- values of the square Euclidean distance for row-standardized data are equal to formulas of (28)-(29), respectively (the D^+ and D^- values of the square Euclidean distance for column-standardized data).

Correlation Similarity (Corr_s) or Cosine Similarity (Cos_s) for Row-Standardized Data:

$$S_i^+ = \frac{1}{n}\sum_{j=1}^{n} y_{ij} I_j^+ \tag{51}$$

$$S_i^- = \frac{1}{n}\sum_{j=1}^{n} y_{ij} I_j^- \tag{52}$$

Correlation Distance (Corr_d) or Cosine Distance (Cos_d) for Row-Standardized Data:

$$D_i^+ = 1 - S_i^+ = 1 - \left(\frac{1}{n}\sum_{j=1}^{n} y_{ij} I_j^+\right) \tag{53}$$

$$D_i^- = 1 - S_i^- = 1 - \left(\frac{1}{n}\sum_{j=1}^{n} y_{ij} I_j^-\right) \tag{54}$$

Circumstance Critique: although the Euclidean distance formula (28)-(29) is not affected by column or row-standardization, the cosine (34)-(35) and correlation (36)-(37) distance formulas are affected. In order to apply (53)-(54), it is necessary that the performance matrix has a row based average of "0" and a standard deviation of "1." To ensure this condition, see the following.

For the row-standardization case, either the criteria (variables) are not to be weighted, so the weight vector must be treated as a "unit vector," or the performance matrix obtained after weighting the criteria has to be standardized again on a row basis.

For the column-standardization case: whether the criterion weighting is done or not, the performance matrix has to be standardized again on a row basis.

For both cases the PIS and NIS vectors must be standardized on a row basis.

3.2.3. Proposed Step 7: Calculating the Overall Performance Index (Ranking Index P_i) for Each Alternative across All Criteria. In this study three different performance indexes were proposed. The significance of these three new different P_i values were tried to emphasize by taking into account "the P_i value suggested by the traditional TOPSIS method" (21) and "the P_i value proposed by Ren et al. [18]"

$$P_i^2 = \sqrt{\left[D_i^+ - \min\left(D_i^+\right)\right]^2 + \left[D_i^- - \max\left(D_i^-\right)\right]^2} \tag{55}$$

As can be understood from the above formula, Ren and et al. [18] calculated the P_i values using the Euclidean distance. For this reason, this value will be called the *Euclidean P_i* value in the study.

Euclidean P_i value: the D^+, D^- plane is established with D^+ at the x-axis and D^- at the y-axis. The point (D_i^+, D_i^-) represents each alternative ($i = 1, 2 \ldots, \text{n}$) and the $(\min(D_i^+), \max(D_i^-))$ point to be the "optimized ideal reference point" (in Figure 2, point A); then the distance from each alternative to point A is calculated by using (55). The graph of the distance is shown in Figure 2. And finally for ranking the preference order, the value obtained for each alternative is sorted from "*small to big*" because the formulas are based on distance concepts.

Proposed P_i values: The ranking index of the traditional TOPSIS method is obtained as the ratio of the NIS to the sum

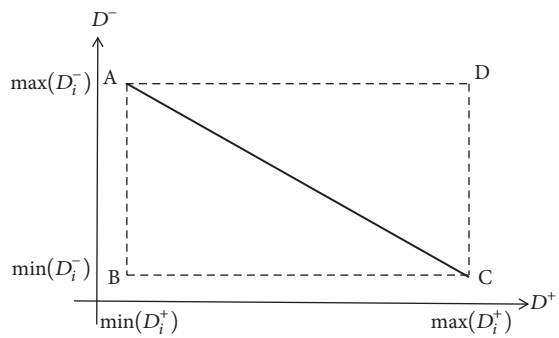

Figure 2: Explanation of the Euclidean distance.

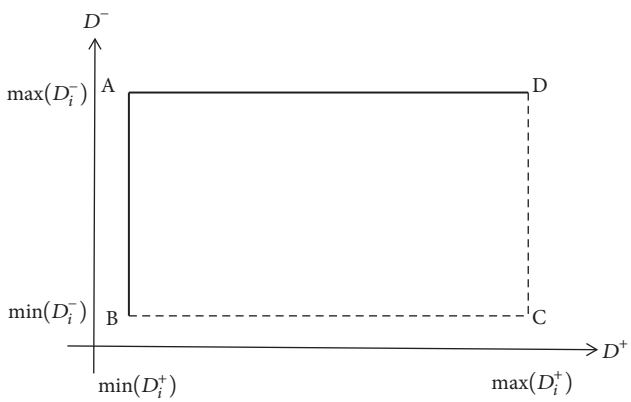

Figure 3: Manhattan distance.

of the NIS and PIS (see (21)). Although it seems reasonable, its validity is questionable and debatable in that it is based on a simple rate calculation. For this reason, researchers have tried various methods to rank alternatives. One of them is the Euclidean P_i value detailed above.

In this study alternative to the Euclidean P_i value (P_i^2) and of course to the traditional P_i value (P_i^1) three different methods have been proposed below. The first two proposed methods include the distances of "*Manhattan*" and "*Chebyshev*" in the L_q distance family, just like the *Euclidean* distance. The latter method is a new global distance measure consisting of the geometric mean of these three distances in the L_q family. The Euclidean, Manhattan, and Chebyshev distances are detailed in Section 2.4. For this reason in this section, it is mentioned that these measures and the new global distance measure are adapted to the (D_i^+, D_i^-) and $[\min(D_i^+), \max(D_i^-)]$ points so that they can sort the alternatives from the best to the less good ones. Just as *Euclidean* P_i (P_i^2) for ranking the preference order, the value obtained for each alternative is sorted from "*small to big*."

(1) Manhattan P_i value (P_i^3) . : the formula for the proposed index based on the Manhattan distance is given in (56) and the graph of the distance is shown with thick lines in Figure 3.

$$P_i^3 = \left|D_i^+ - \min\left(D_i^+\right)\right| + \left|D_i^- - \max\left(D_i^-\right)\right| \tag{56}$$

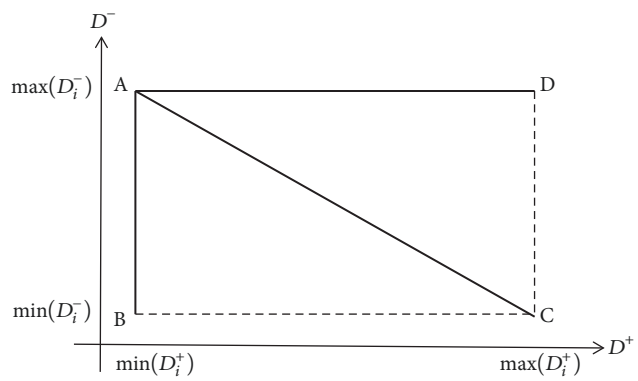

Figure 4: Chebyshev distance.

(2) Chebyshev P_i value (P_i^4) . : the proposed index based on the Chebyshev distance is given in (57). The graph of the distance is shown with thick lines in Figure 4.

$$P_i^4 = \max\left[\left|D_i^+ - \min\left(D_i^+\right)\right|, \left|D_i^- - \max\left(D_i^-\right)\right|\right] \tag{57}$$

(3) Global Distance P_i value (P_i^5) . : in global distance value Euclidean, Manhattan and Chebyshev are considered as local distance. The global distance measure is based on the geometric average of these three local distance measures (see Section 2.5).

$$P_i^5 = \sqrt[3]{P_i^2 . P_i^3 . P_i^4} \tag{58}$$

3.3. Formulations of the DSC TOPSIS Method. According to the standardization method used (Structure of the Performance Matrix) and whether the criteria are weighted or not the distance and similarity values mentioned above can be calculated by means of which formulas (Proposed Method Formulas) are shown in Table 1.

Explanations about the cases in Table 1:

(i) Case 1, Case 2, Case 3, and Case 4 are the cases where only one of the column or row-standardization methods are applied, while the remaining last four cases, Case 5, Case 6, Case 7, and Case 8, showed the conditions under which "double standardization" are applied.

(ii) In Case 1, Case 3, Case 5, and Case 7 the "standardized matrix" will be also "performance matrix" because any weighting method is not used.

(iii) In Case 3, Case 4, Case 5, and Case 6 after the row-standardization the "PIS and NIS values" should be also standardized according to "row-standardization." This correction is needed since the PIS and NIS are considered as a single value in the column-standardization and as a vector in row-standardization.

Table 1: Implementation of the proposed method.

Cases	Structure of the Performance Matrix			Proposed Method Formulas					
	Column-Standardized	Row-Standardized	Weighting	Sq_Euc	Corr_s	Cos_s	Cos_d	Cos_d	Proposed D
Case 1	Used	Unused	Unused	Equations (28)-(29)	Equations (30)-(31)	Equations (32)-(33)	Equations (34)-(35)	Equations (36)-(37)	Equations (26)-(27)
Case 2	Used	Unused	Used	Equations (28)-(29)	Equations (30)-(31)	Equations (32)-(33)	Equations (34)-(35)	Equations (36)-(37)	Equations (26)-(27)
Case 3	*Unused*	*Used***	*Unused*	*Equations (28)-(29)*	*Equations (51)-(52)*	*Equations (51)-(52)*	*Equations (53)-(54)*	*Equations (53)-(54)*	*Equations (49)-(50)*
Case 4	*Unused*	*Used***	*Used*	*Equations (28)-(29)*	*Equations (51)-(52)*	*Equations (51)-(52)*	*Equations (53)-(54)*	*Equations (53)-(54)*	*Equations (49)-(50)*
Case 5	*Used (First)*	*Used*** *(Second)*	*Unused*	*Equations (28)-(29)*	*Equations (51)-(52)*	*Equations (51)-(52)*	*Equations (53)-(54)*	*Equations (53)-(54)*	*Equations (49)-(50)*
Case 6	*Used (First)*	*Used*** *(Second)*	*Used*	*Equations (28)-(29)*	*Equations (51)-(52)*	*Equations (51)-(52)*	*Equations (53)-(54)*	*Equations (53)-(54)*	*Equations (49)-(50)*
Case 7	Used (Second)	Used* (First)	Unused	Equations (28)-(29)	Equations (30)-(31)	Equations (32)-(33)	Equations (34)-(35)	Equations (36)-(37)	Equations (26)-(27)
Case 8	Used (Second)	Used* (First)	Used	Equations (28)-(29)	Equations (30)-(31)	Equations (32)-(33)	Equations (34)-(35)	Equations (36)-(37)	Equations (26)-(27)

*: Standardize criteria according to row-standardization.

**: First standardize criteria according to row-standardization and then standardize PIS and NIS values according to row-standardization.

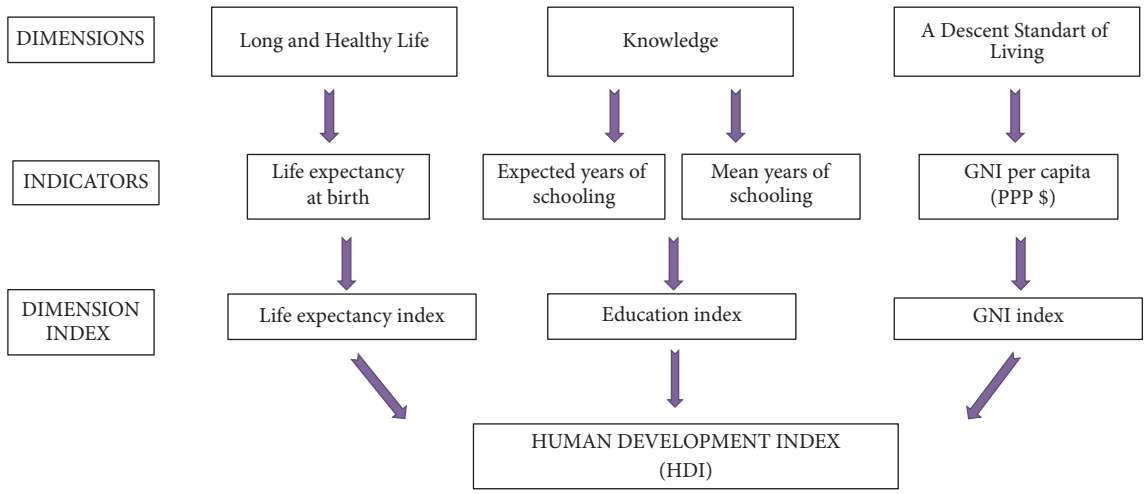

Figure 5: The dimensions and indicators of HDI.

Note. In the application part of the study, Case 5, Case 6, Case 7, and Case 8, where double standardization is applied, will not be included because they are partly addressed in Case 1, Case 2, Case 3, and Case 4, where one-way (row or column) standardization is applied.

The application types that can be used for the cases detailed in Table 1 can be summarized as follows.

Case 1 and Case 2: in these two cases where column-standardization is used, alternatives for each criterion are brought to the same unit. In Case 1, the criteria are handled without weighting and in Case 2 they are weighted. In this study, *equal* weighting method was preferred for comparison. In Case 2 different weighting methods such as Saaty, point, best-worst, entropy, swara, etc. can also be used.

Case 3 and Case 4: for these two cases where row-standardization is used, the criteria for each alternative are brought to the same unit. In Case 3 the criteria are unweighted and in Case 4 they are weighted. For Case 4, it is possible to apply different weighting methods just as in Case 2. At these cases the PIS and NIS values obtained after standardization of the decision matrix are standardized according to row-standardization.

Case 5, Case 6, Case 7, and Case 8: these are the cases where double standardization is used. In Case 5 and Case 6 following the standardization of the decision matrix according to double standardization (first by row, second by column) PIS and NIS values are also standardized according to the rows because the latest row-standardization is applied.

4. Case Study of the Proposed Methods

In this section all of the proposed methods were applied on the HDI data. Therefore, in the following subsections, information about HDI will be given first, and then implementation steps of the proposed method will show on criteria and alternatives that constitute HDI. Finally, the results obtained will be compared with the HDI value.

4.1. Human Development Index. Human development, or the human development approach, is about expanding the richness of human life, rather than simply the richness of the economy in which human beings live [26]. Developed by an economist Mahbub ul Haq, this approach emphasizes that monetary indicators such as Gross National Income (GNI) per capita alone are not enough to measure the level of development of countries. In HDR, the term GNI is defined as "aggregate income of an economy generated by its production and its ownership of factors of production, less the incomes paid for the use of factors of production owned by the rest of the world, converted to international dollars using purchasing power parity (PPP) rates, divided by mid-year population." [27]

It has been pointed out that the opportunities and choices of people have a decisive role in the measurement. These are to live long and healthy, to be educated and to have access to resources for a decent standard of living [28]. The human development approach was transformed into an index with a project supported by UNDP in 1989 and named HDI. In this way, it is aimed to measure the development levels of the world states better. After introducing the HDI, the UNDP published a report in 1990, in which the index was computed for each country as a measure of the nation's human development. Since then UNDP has continued publishing a series of annual Human Development Reports (HDRs) [5].

The first Human Development Report introduced the HDI as a measure of achievement in the basic dimensions of human development across countries. This somewhat crude measure of human development remains a simple unweighted average of a nation's longevity, education, and income and is widely accepted in development discourse. Before 2010 these indicators are used to measure HDI. Over the years, some modifications and refinements have been made to the index. In HDI 20th anniversary edition in 2010, the indicators calculating the index were changed. Figure 5 shows the dimensions and indicators of the HDI index [26].

As can be seen from Figure 1, HDI is a composite index of three dimensions which are a decent standard

Table 2: The first and last five countries with high HDI, I_{Life}, $I_{Education}$, and I_{Income} values.

No	HDI	I_{Life}	$I_{Education}$	I_{Income}
1	Norway	Hong Kong, China (SAR)	Australia	Liechtenstein
2	Switzerland	Japan	Denmark	Singapore
3	Australia	Italy	New Zealand	Qatar
4	Germany	Singapore	Norway	Kuwait
5	Singapore	Switzerland	Germany	Brunei Darussalam
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
184	Eritrea	Guinea-Bissau	Guinea	Madagascar
185	Sierra Leone	Mozambique	Ethiopia	Togo
186	South Sudan	Nigeria	Sudan	Mozambique
187	Mozambique	Angola	Mali	Malawi
188	Guinea	Chad	Djibouti	Guinea

of living, knowledge, and long and healthy life. A decent standard of living dimension which contained GNI per capita, create "GNI Index (Income Index-I_{Income})." Likewise, life expectancy at birth at the long and healthy life generate "Life Expectancy Index (Life Index-I_{Life})." And finally both mean years of schooling and expected years of schooling which is in dimension knowledge create "Education Index ($I_{Education}$)."

In order to calculate the HDI first these three core dimensions are put on a common (0, 1) scale. For this purpose the following equation is used:

$$x'_{ij} = \frac{x_{ij} - \min\left(x_{ij}\right)}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \tag{59}$$

After that, the geometric mean of the dimensions is calculated to produce the HDI (UNDP, 2011). This formula is given in

$$HDI = \sqrt[3]{I_{Life}.I_{Education}.I_{Income}} \tag{60}$$

The world countries are ranked according to the HDI values calculeted from (60).

4.2. Implementation of the Proposed Method. In this section the degree of similarity of the alternatives between each alternative and the PIS and the NIS is calculated with proposed D^+ and D^- value at (26)-(27) for column-standardization and at (49)-(50) for row-standardization, respectively. The overall performance index for each alternative across all criteria is calculated with proposed P_i values at (56)-(57)-(58) used to rank countries in terms of HDI. The HDI value is basically based on the criteria of life expectancy at birth, mean years of schooling, expected years of schooling, and GNI per capita, as detailed above. These criteria were used to calculate the HDI value by being reduced to three dimensions: Income Index, Life Index, and Education Index.

From this point of view, in order to operate the DSC TOPSIS method proposed in this study, the development level of the preferred countries and the problem of deciding to create a new HDI were discussed through these three dimensions. Since 188 countries were considered in the HDR report published in 2016 (prepared with 2015 values), the initial decision matrix created in the implementation part of the study was formed from 188 alternatives. Income Index, Life Index, and Education Index are considered as criteria so that the initial decision matrix was formed from 188 alternatives and 3 criteria. For the tables not to take up too much space, the data and the results of the first five countries in alphabetical order from 188 countries are given. In terms of giving an idea before the steps of the DSC TOPSIS method are implemented, the first and last five countries with the highest and lowest Income Index, Life Index, and Education Index values in addition to HDI value are given in Table 2, respectively.

Table 3: The original data for the first five countries: Decision matrix.

Country	I_{Life}	$I_{Education}$	I_{Income}
Afghanistan	0.626	0.398	0.442
Albania	0.892	0.715	0.699
Algeria	0.847	0.658	0.741
Andorra	0.946	0.718	0.933
Angola	0.503	0.482	0.626
.	.	.	.
.	.	.	.
.	.	.	.
Weights	*0.333*	*0.333*	*0.333*
Mean	0.790	0.639	0.687
St. Dev.	0.127	0.174	0.180

Step 1 (determining the decision matrix). In this matrix 188 countries, which have been investigated in the 2016 HDR, are considered to be alternatives and the three HD dimension formed the criteria. The decision matrix is shown at Table 3 for the first ten countries.

Table 4: Standardized data (or performance matrix of unweighting data) for the first five countries.

Country	Column-Standardization					Row-Standardization				
	I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.	I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.
Afghanistan	-1.289	-1.386	-1.363	*-1.346*	*0.041*	1.391	-0.918	-0.473	*0.000*	*1.000*
Albania	0.801	0.439	0.069	*0.436*	*0.299*	1.410	-0.614	-0.797	*0.000*	*1.000*
Algeria	0.448	0.111	0.303	*0.287*	*0.138*	1.271	-1.172	-0.099	*0.000*	*1.000*
Andorra	1.226	0.456	1.372	*1.018*	*0.402*	0.768	-1.412	0.644	*0.000*	*1.000*
Angola	-2.255	-0.902	-0.338	*-1.165*	*0.805*	-0.535	-0.866	1.401	*0.000*	*1.000*
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
Weights	*0.333*	*0.333*	*0.333*			*0.333*	*0.333*	*0.333*		
Mean	*0.000*	*0.000*	*0.000*			*1.025*	*-0.780*	*-0.245*		
St. Dev.	*1.000*	*1.000*	*1.000*			*0.595*	*0.604*	*0.750*		

Table 5: Performance matrix for the first five countries.

Country	Column-Standardization					Row-Standardization				
	I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.	I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.
Afghanistan	-0.430	-0.462	-0.454	-0.449	0.014	0.464	-0.306	-0.158	*0.000*	*0.333*
Albania	0.267	0.146	0.023	0.145	0.100	0.470	-0.205	-0.266	*0.000*	*0.333*
Algeria	0.149	0.037	0.101	0.096	0.046	0.424	-0.391	-0.033	*0.000*	*0.333*
Andorra	0.409	0.152	0.457	0.339	0.134	0.256	-0.471	0.215	*0.000*	*0.333*
Angola	-0.752	-0.301	-0.113	-0.388	0.268	-0.178	-0.289	0.467	*0.000*	*0.333*
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
Weights	*0.333*	*0.333*	*0.333*			*0.333*	*0.333*	*0.333*		
Mean	*0.000*	*0.000*	*0.000*			*0.342*	*-0.260*	*-0.082*		
St. Dev.	*0.333*	*0.333*	*0.333*			*0.198*	*0.201*	*0.250*		

Step 2 (determining the weighting vector). Since the purpose is to explain the operation of the model rather than the weighting, the criteria are handled without any weighting (*unweighted*) and with "*equally weighted*" in the study. Just as in the traditional TOPSIS method, in the proposed method can also be given different weights for the criteria (will be considered as the future research topic).

"Equal weighting" is a method of giving equal importance to the criteria being considered. Since three criteria are considered in the study, the weight of each criterion is determined as "*1/3 = 0.333*." The weights for the criteria are shown in the bottom row of Table 3.

Step 3 (standardized the decision matrix). Before ranking the countries, to put data on a common scale standardization method are used column-standardization and row-standardization. It was performed with (24). The result is shown in Table 4.

In the column-standardization part of Table 4, while the alternatives (countries) are brought to the same unit for each criterion (Life, Education, and Income), in the row-standardization part, the criteria for each alternative are brought to the same unit.

Step 4 (calculating the performance matrix). The performance matrix is obtained by multiplying the weight vector by the matrix of the standardized values (Table 5).

It should be reminded again at this point that if the criterion weighting is not performed, then the matrix obtained as a result of column or row-standardization (standardized data, Table 4) would also be considered as a "performance matrix."

Step 5 (determining the PIS and the NIS). The PIS and the NIS are attainable from all the alternatives (188 countries) across all three criteria according to (15) and (17), respectively. These values are shown in Table 6.

Step 6 (calculating the degree of distance of the alternatives between each alternative and the PIS and the NIS). After the column and row-standardizations, in this step first the degree of similarities and distances of the alternatives between each alternative and the PIS and the NIS are calculated. And then from these values the degree of *proposed distances* of the alternatives between each alternative and the PIS and the NIS is calculated (Table 7).

Step 7 (calculating the overall performance index). The overall proposed performance index for each alternative

Table 6: PIS (I^+) and NIS (I^-) value.

Weighting Status	PIS and NIS	Column-Standardization					Row-Standardization				
		I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.	I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.
Unweighted	I^+	1.548	1.728	1.746	*1.674*	*0.089*	1.414	1.358	1.401	*1.391*	*0.024*
	I^-	-2.711	-2.491	-2.338	*-2.513*	*0.153*	-1.404	-1.414	-1.414	*-1.411*	*0.005*
Weighted	I^+	0.516	0.576	0.582	*0.558*	*0.030*	0.471	0.453	0.467	*0.464*	*0.008*
	I^-	-0.904	-0.830	-0.779	*-0.838*	*0.051*	-0.468	-0.471	-0.471	*-0.470*	*0.002*

Table 7: PIS (I^+) and NIS (I^-) value for Case 4.

Row-Standardization				
I_{Life}	$I_{Education}$	I_{Income}	Mean	St. Dev.
0.958	-1.380	0.422	*0.000*	*1.000*
1.414	-0.705	-0.710	*0.000*	*1.000*

across all three criteria is calculated based on (21)-(55)-(56)-(57)-(58). The results obtained by applying the DSC TOPSIS method according to the "cases" detailed above and the results of "ranking" performed in Step 8 are given in Tables 8, 9, 10, and 11, respectively. The tables are constructed to contain proposed P_i values (P_i^3-(56), P_i^4-(56), P_i^5-(56)) and their ranking, as well as the values and ranking of P_i^1 (21), P_i^2 (55), HDI, and traditional TOPSIS method (P). Thus, all methods are provided to be implemented together (Tables 8, 9, 10, and 11).

Table 8 shows the results obtained from the application of Case 1. In Case 1, after the column-standardization of the decision matrix was carried out (in other words, after the countries are brought to comparable level for Life, Education, and Income criteria, respectively) the proposed DSC TOPSIS method was applied without any weighting to the criteria.

The application results of Case 2 were given in Table 9. Unlike Case 1 in Case 2, after the column-standardization of the decision matrix was performed, the proposed DSC TOPSIS method was applied with equal weight (different weighting methods can also be used) to the criteria.

Table 10 shows the results obtained from the application of Case 3. Unlike Case 1 in Case 3, after the row-standardization of the decision matrix was made (in other words, after Life, Education, and Income criteria are brought to comparable level for each country) the proposed DSC TOPSIS method was applied without any weight to the criteria.

The application results of Case 4 were given in Table 11. In Case 4, unlike Case 3, after the row-standardization of the decision matrix was performed, the proposed DSC TOPSIS method was applied by giving equal weight to the criteria. As in Case 2, in Case 4, weighting methods other than the equal weighting method can be used.

Step 8 (ranking the alternatives). The alternatives could be ranked in the descending order of the proposed P_i indexes values. In Tables 12 and 13, the first five countries with the highest value and the last five countries with the lowest value are listed according to the ranking results obtained for Case 1, Case 2, Case 3, Case 4, and Case 5, respectively, in alphabetical order. Additionally in Figures 6 and 7, the values of all the indexes computed during the study, mainly HDI, are handled together for all countries. Thus, it is possible to compare development levels of countries according to different indexes. In the graphs, the traditional TOPSIS index is denoted as "***P***" and P_i^1, P_i^2, P_i^3, P_i^4, P_i^5 are denoted as "***P1, P2, P3, P4, P5***," respectively. In accordance with the equal weighting method used in Case 2, although all the P_i values are different for Case 1 and Case 2, the results are given together because the ranks are the same.

If Table 12 is examined, Norway for HDI0, P and P_i^1, France for P_i^2 and P_i^5, Japan for P_i^3, and Korea for P_i^4 have become the most developed countries. Other results in the table can be interpreted similarly.

Figure 6 shows that although there are some differences in the ranking according to development levels of countries, both HDI and other indexes are similar.

According to Table 13 and Figure 7 it is observed that indices give similar results even though there are some differences.

In Figures 6 and 7, the x-axis represents the countries (order numbers 1 to 188 of the 188 world countries sorted in alphabetical order) and the y-axis represents a range of 0 and 1 for each index (for each line in the figures).

4.3. Discussion of Results. Findings obtained from the study: in DSC TOPSIS method, standardization, weighting, and performance indexes were found to be important in order to rank the alternatives. It is possible to interpret the results obtained in the application part of the study as follows.

(i) In order to sort and compare the alternatives, HDI values, the results of the traditional TOPSIS method and the results of the proposed DSC TOPSIS method were given together and a general comparison was made. With the DSC TOPSIS method, a new measure that is more sensitive and stronger than the measure used in the traditional TOPSIS method was proposed. The reason why the proposed unit of measurement is expressed as more sensitive and stronger is the use of similarity and correlation distances in addition to the Euclidean distance used in the traditional TOPSIS method in order to rank the alternatives. In other words, DSC TOPSIS uses three units that can be used to compare alternatives: distance, similarity, and correlation. From the results of the application it was observed that HDI, TOPSIS, and DSC TOPSIS results are not exactly the same and show some differences.

Table 8: The overall performance index P_i values for the first five countries-Case 1.

Country	HDI		P		P_i^1		P_i^2		P_i^3		P_i^4		P_i^5	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Afghanistan	0.479	169	0.281	172	0.061	182	7.035	185	9.938	185	5.197	172	7.136	186
Albania	0.764	75	0.697	70	0.787	78	1.520	32	2.119	40	1.241	27	1.587	32
Algeria	0.745	83	0.667	83	0.793	75	1.761	46	2.468	53	1.402	41	1.827	47
Andorra	0.858	32	0.819	33	0.879	52	1.496	29	1.948	32	1.386	40	1.593	33
Angola	0.533	150	0.338	155	0.166	153	5.396	138	6.304	128	5.303	176	5.650	142

Table 9: The overall performance index P_i value for the first five countries-Case 2.

Country	HDI		P		P_i^1		P_i^2		P_i^3		P_i^4		P_i^5	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Afghanistan	0.479	169	0.281	172	0.061	182	3.382	185	4.778	185	2.499	172	3.431	186
Albania	0.764	75	0.697	70	0.787	78	0.731	32	1.019	40	0.597	27	0.763	32
Algeria	0.745	83	0.667	83	0.793	75	0.847	46	1.186	53	0.674	41	0.878	47
Andorra	0.858	32	0.819	33	0.879	52	0.719	29	0.937	32	0.667	40	0.766	33
Angola	0.533	150	0.338	155	0.166	153	2.594	138	3.031	128	2.549	176	2.716	142

Table 10: The overall performance index P_i value for the first five countries-Case 3.

Country	HDI		P		P_i^1		P_i^2		P_i^3		P_i^4		P_i^5	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Afghanistan	0.479	169	0.006	171	0.079	149	3.609	119	3.954	113	3.590	155	3.714	117
Albania	0.764	75	0.230	114	0.007	170	3.682	169	4.307	142	3.617	169	3.856	152
Algeria	0.745	83	0.086	141	0.597	71	3.438	75	3.561	75	3.436	100	3.478	75
Andorra	0.858	32	0.464	94	0.970	15	2.789	26	2.814	26	2.788	29	2.797	26
Angola	0.533	150	0.875	48	0.706	62	1.527	1	2.158	1	1.113	1	1.542	1

This is the expected result because the measurement units used in each method are different. At this point, which method is preferred depends on the decision-maker's opinion.

(ii) In the DSC TOPSIS method, although the performance indexes for Case 1 and Case 2, which have the objective to bring the alternatives to the same unit for each criterion, have different values, the ranking values are the same. This is expected because the equal weighting method is actually equivalent to the situation where there is no weighting. Of course, if different weights are used for the criteria in Case 2, it is highly probable that both different performance index values and different rankings can be obtained.

(iii) Case 3 and Case 4, which bring the criteria to the same unit for each alternative, refer to situations that are performed without weighting and equal weighting, respectively. The situation described above is also valid here and the results of the indexes are the same.

(iv) Which standardization method is preferred depends on the decision-maker's opinion and the nature of the problem being addressed. The decision problem in this study was the calculation of HDI and the proposed solution method was DSC TOPSIS. When the structure of the decision problem is examined, it can be concluded that it is more reasonable to prefer Case 1 and Case 2 where column-standardization is used. Considering the advantage of the fact that different weighting methods can be tried as well as equal weighting in Case 2, it is obvious that the most reasonable solution would be Case 2.

(v) Which performance index is preferred to rank the alternatives depends on the decision-maker. At this point, it is expected that P^5, which is the average of all performance indexes proposed in the study, is preferred.

5. Conclusions

There are lots of efficient MCDM methods which are suitable for the purpose of ranking alternatives across a set of criteria. None of MCDM methods in the literature gives a complete superiority over the other. Each of them can give different results according to their main purposes. For this reason, the method to be applied should be decided according to the structure of the decision problem and the situation to be investigated. In some cases, the results obtained by trying different MCDM methods are compared and the most reasonable solution is selected.

Table 11: The overall performance index P_i value for the first five countries-Case 4.

Country	*HDI*		$\boldsymbol{P}$		P_i^1		P_i^2		P_i^3		P_i^4		P_i^5	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Afghanistan	0.479	169	0.006	171	0.441	149	1.203	119	1.318	113	1.197	155	1.238	117
Albania	0.764	75	0.230	114	0.390	170	1.227	169	1.436	142	1.206	169	1.285	152
Algeria	0.745	83	0.086	141	0.511	71	1.146	75	1.187	75	1.145	100	1.159	75
Andorra	0.858	32	0.464	94	0.623	15	0.930	26	0.938	26	0.929	29	0.932	26
Angola	0.533	150	0.875	48	0.622	62	0.509	1	0.719	1	0.371	1	0.514	1

Table 12: Top and bottom five countries with high and low level of development-Case 1 and Case 2.

No	*HDI*	$\boldsymbol{P}$	P_i^1	P_i^2	P_i^3	P_i^4	P_i^5
1	Norway	Norway	Norway	France	Japan	Korea (Republic of)	France
2	Australia	Switzerland	Finland	Korea (Republic of)	France	France	Korea (Republic of)
3	Switzerland	Australia	Netherlands	Japan	Korea (Republic of)	Israel	Japan
4	Germany	Netherlands	Switzerland	Israel	Israel	Japan	Israel
5	Denmark	Germany	United States	Spain	Spain	Spain	Spain
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
184	Burundi	Guinea-Bissau	Central African Republic	Burkina Faso	Burkina Faso	Chad	Burkina Faso
185	Burkina Faso	Mozambique	Guyana	Afghanistan	Afghanistan	Benin	Gambia
186	Chad	Sierra Leone	South Sudan	Gambia	Gambia	Guyana	Afghanistan
187	Niger	Chad	Chad	Niger	Niger	Guinea-Bissau	Niger
188	Central African Republic	Central African Republic	Congo	Guinea	Guinea	Congo	Guinea

Undoubtedly, the oldest and valid method used to rank the alternatives is distance. The concept of distance forms the basis of the TOPSIS method (it was called "traditional TOPSIS" in the study). In TOPSIS (the steps of implementation are given in detail in Section 3.1), the best result and the worst result are determined first. Then, each of the alternatives discussed determines the distance between the best result and the worst result. A general ranking value is calculated by evaluating the best solution distance and the worst solution distance values, and the alternatives are sorted according to the size of these values. It is desirable that the alternatives in the method are as close as possible to the best solution, and the worst solution is away from the other side.

As previously stated, "normalizing the decision matrix (Step 3)," "calculating the distance of positive and negative-ideal solutions (Step 6)," and "calculating the overall performance index for each alternative across all criteria (Step 7)" of the traditional TOPSIS method steps can be examined, improved, or modified. The aim of the study is to draw attention to the above-mentioned weaknesses of the traditional TOPSIS method and to propose new solutions and approaches. For this purpose *"column, row, and double standardization"* were substituted for "normalization approach," *"a new measure based on the concepts of distance, similarity, and correlation (DSC)"* was substituted for "Euclidean distance," and *"new sorting approaches based on the concept of distance (performance index)"* were substituted for "simple ratio." This new MCDM method is called DSC TOPSIS.

The DSC TOPSIS method is particularly remarkable in its *new measure and new performance indexes*. Because in addition to the distance method used in the traditional TOPSIS, this new measure also includes similarity and correlation effects for sorting alternatives. Just as in the distance method, alternatives are compared with positive and negative-ideal solutions in the similarity method. In the correlation method, alternatives are compared according to the concept of relationship. It has been tried to achieve a stronger evaluation criterion by combining these three measurement techniques. In the proposed new performance indexes, distance concepts were used. Thus, more powerful sorting techniques have been tried to be obtained.

Table 13: Top and bottom ten countries with high and low level of development-Case3 and Case 4.

No	*HDI*	***P***	P_i^1	P_i^2	P_i^3	P_i^4	P_i^5
1	Norway	Azerbaijan	Austria	Angola	Angola	Angola	Angola
2	Australia	France	Hong Kong, China (SAR)	United States	United States	United States	United States
3	Switzerland	Lesotho	Azerbaijan	Nigeria	Nigeria	Nigeria	Nigeria
4	Germany	Finland	Libya	Botswana	Botswana	Botswana	Botswana
5	Denmark	Spain	Chad	Equatorial Guinea	Equatorial Guinea	Equatorial Guinea	Equatorial Guinea
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
184	Burundi	Niger	Israel	Malawi	Palau	Argentina	Slovenia
185	Burkina Faso	El Salvador	Argentina	Bolivia (Plurinational State of)	Latvia	Nepal	Armenia
186	Chad	Cabo Verde	Nepal	Palestine, State of	Estonia	Ghana	Liberia
187	Niger	Dominica	Ghana	Denmark	Fiji	Haiti	Burundi
188	Central African Republic	Ethiopia	Haiti	Uganda	Ukraine	Lithuania	Hungary

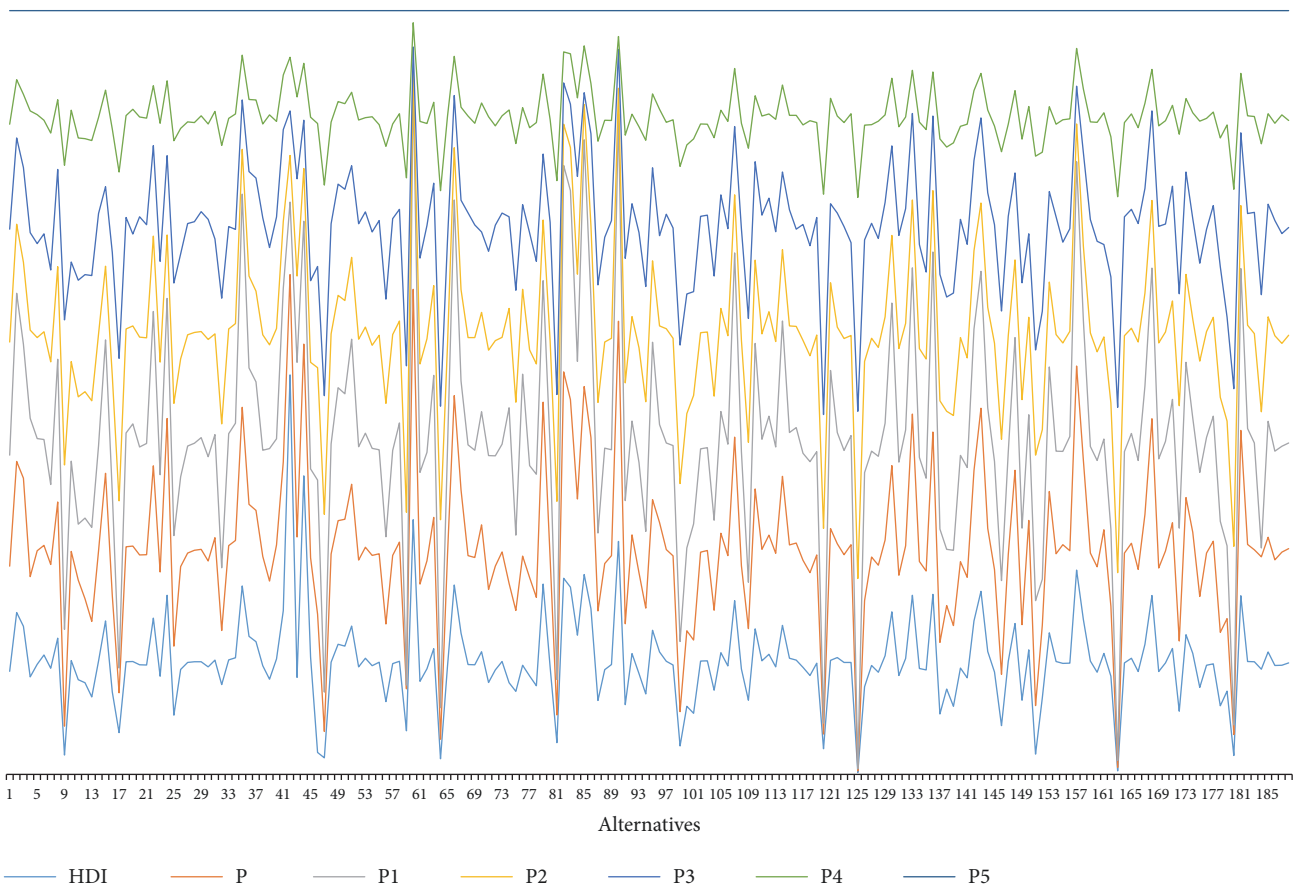

Figure 6: Comparison of the development levels of countries for all indices, Case 1 and Case 2.

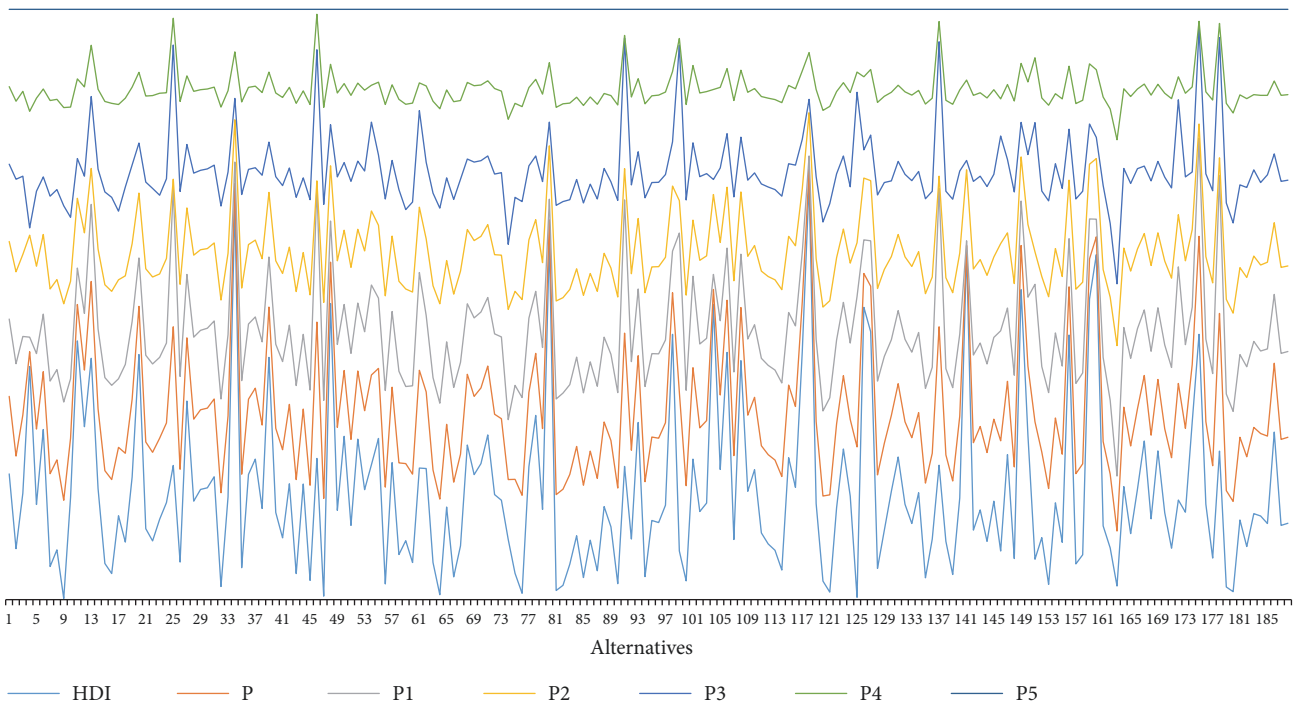

Figure 7: Comparison of the development levels of countries for all indices, Case 3 and Case 4.

The formulation of the DSC TOPSIS method is detailed for the eight different cases defined (Table 1). The first four cases are exemplified on the HDI data in the *"Implementation of the Proposed Method"* subsection (Section 4.2) because they represent the basis of the DSC TOPSIS method (they contain the last four cases partly). HDI is an index developed to rank countries according to their level of development. The index is basically based on Income Index, Life Index, and Education Index variables and is calculated by geometric mean. One of the most important reasons for considering the HDI in the study is that it is not very desirable to calculate the index based on the geometric mean and that there are various criticisms on it. With this paper, the order of development for the countries of the world has been tried to be obtained by a different method. In a more explicit way, a different proposal was made for the calculation method of HDI calculated by UNDP. It was concluded that Case 2 and P^5 performance index could be preferred when using DSC TOPSIS method in the calculation of HDI.

In conclusion, the effect of the proposed DSC TOPSIS method on the following concepts is discussed in all aspects:

(i) different standardization methods,

(ii) different weighting methods,

(iii) different performance indexes.

In the study, the standardization of the decision matrix in different ways is also emphasized. According to the preferred standardization type, it is emphasized that the decision matrix will have different meanings and different results will be obtained. The only issue to be considered in the application of the method is to decide the standardization method to be applied. The following topics can be given as examples for future applications.

(i) establishing different versions of the new measurement proposed by the DSC TOPSIS method: e.g., combining the concepts of distance, similarity, and correlation with a different technique instead of a geometric mean or experimenting with different combinations of these concepts together (distance and similarity, distance and correlation, similarity and correlation, etc.),

(ii) suggesting different ranking index (P_i) formulas to sort alternatives,

(iii) experiment of different weighting techniques in DSC TOPSIS method,

(iv) blurring the DSC TOPSIS method: fuzzy DSC TOPSIS.

6. Limitations and Future Research

The proposed DSC TOPSIS method does not have any limitations, and the method can be easily applied to all decision problems where traditional TOPSIS can be applied.

Data Availability

Data are obtained from "http://hdr.undp.org/en/humandev, United Nations Development Programme Human Development Reports" website.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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