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Identifying the Right Policies for Increasing the Efficiency of the Renewable Energy Transition With a Novel Fuzzy Decision-Making Model

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ABSTRACT

Necessary improvements should be made to the determinants of renewable energy transition. However, it is necessary to give priority to the issues that are more important while making improvements to this process since all improvements cause cost increase. Therefore, a new analysis is needed in which the most important ones among these criteria will be determined. The purpose of this study is to identify the most essential items for renewable energy transition. Within this context, five criteria are selected based on the literature review results. Spherical fuzzy (TOPSIS-based DEMATEL) TOP-DEMATEL methodology is taken into consideration to calculate the weights of these indicators. In the second part of the study, alternatives are ranked with Spherical fuzzy ranking technique by geometric mean of similarity ratio to optimal solution (RATGOS). In this context, BRICS countries (Brazil, Russia, India, China, South Africa) are selected as alternatives. The main contribution is that a new method (RATGOS) is created while considering geometric mean in proportional concepts. On the other side, a new methodology (TOP-DEMATEL) is also proposed to overcome criticisms in DEMATEL. It is concluded that technological development plays the most important role for the success of renewable energy transition. Similarly, finding effective financial source is also very important in this condition. The ranking results also demonstrate that China and Russia are the most successful countries regarding renewable energy transition. However, it is also defined that South Africa and India are less successful in renewable energy transition in comparing with other BRICS countries. It is understood that technological development plays a critical role in increasing the efficiency of the renewable energy transition process. Thanks to the use of up-to-date technology, it is possible to use energy resources more efficiently. Technological developments are also necessary for the efficiency of energy storage processes. Variations in climatic conditions cause irregularities in the energy production process. Thanks to the efficient energy storage processes, it is possible to solve this problem.

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1. Introduction

Renewable energy transition refers to the preference of clean energy sources instead of fossil fuels in energy production. In this way, it is aimed to minimize the fossil fuels that cause carbon emissions. It is possible to talk about many advantages of this transition. Air pollution can be reduced by preferring renewable sources in energy production. This makes a significant contribution to environmental sustainability. In addition, renewable energy sources can also reduce dependence on energy imports. In this way, businesses are less affected by the volatility in energy prices [1]. The transition to renewable energy also contributes to the advancement of technology. To use these energy types effectively, it is necessary to have up-to-date technology. This situation encourages enterprises to invest in technological development.

For the renewable energy transition processes to be successful, some issues need to be considered. The adequacy of legal regulations contributes significantly to increasing the efficiency of this process. Owing to the establishment of the necessary regulations, the confidence of the investors in these projects will increase. This will contribute significantly to the development of the projects. On the other hand, technological development is another necessary issue to increase the success in this process. Thanks to new research and development studies, new technology will be reached, and this will allow to reduce the costs [2]. This situation may attract more attention of investors. It is essential to obtain the necessary financial resources for the development of these projects. In this process, it is important to consider innovative financial resources.

There are many different aspects to consider in the renewable energy transition process. Improving these issues is very important to increase the efficiency of this process. On the other hand, the improvement of many variables causes the costs to rise too much. Therefore, it is necessary to give priority to the issues that are more important while making improvements to this process. A new analysis is needed in which the most important ones among these criteria will be determined. Accordingly, this study aims to find the most essential items for renewable energy transition. For this purpose, five criteria are selected based on the literature review results. Spherical fuzzy TOP-DEMATEL methodology is taken into consideration to calculate the weights of these indicators. In the second part of the study, alternatives are ranked with Spherical fuzzy RATGOS. In this context, BRICS countries (Brazil, Russia, India, China, South Africa) are selected as alternatives.

The main contributions of this study are given as follows. (i) RATGOS method is generated to rank alternatives. Similar techniques in the literature are criticized by the scholars [3]. For example, some studies underlined that using Euclidian distance is not appropriate to compute the distances to the negative ideal solutions. Because of this need, RATGOS approach is proposed while considering geometric mean in proportional concepts. (ii) The most critical determinants of renewable energy transition are presented. This situation helps the investors focus on more important factors. Otherwise, it is not financially optimal to make lots of improvements at the same time. (iii) A new methodology is proposed by the name of TOP-DEMATEL. Many different scholars criticized classical DEMATEL technique. In this context, DEMATEL gives the same weights inappropriately in case of symmetrical expert evaluations [4]. To overcome this problem, TOP-DEMATEL method is generated. This new technique has a positive influence on methodological originality of the study.

The second part includes literature review. TOP-DEMATEL and RATGOS techniques are explained in the third part. The fourth part focuses on analysis results. Conclusion is given in the fifth part.

2. Literature Review

Legal regulations are of great importance to increase the efficiency of the renewable energy transition process. Xin-Gang and Ying [5] stated that thanks to these regulations, issues such as tax advantages and economic incentives will be determined more clearly. This situation increases the interest of investors in renewable energy projects [6]. In addition, Du et al. [7] identified that making the necessary legal regulations contributes to the increase of investors' confidence in these projects. This contributes significantly to the development of these projects. Moreover, Wang et al. [8] determined that with the correct establishment of the legal framework, the auditing of processes can be much easier. Balcilar et al. [9] also discussed that establishing an effective control mechanism also helps to detect problems that may be encountered in the project early. Thus, necessary measures can be taken at an early stage and this will allow the problems not to grow.

Technological development plays a critical role in increasing the efficiency of the renewable energy transition process. Murshed [10] defined that thanks to these developments, it is possible to use energy more efficiently. This helps to reduce the costs of the projects. On the other hand, Chen et al. [11] underlined that technological developments also contribute to reducing the costs of renewable energy projects. This will increase the profitability of these projects. As a result, investors can focus more on these projects. Moreover, Irfan et al. [12] concluded that new technologies enable the efficiency of energy storage processes to be increased. This situation helps to minimize the negative effects of climate differences in renewable energy projects. Furthermore, Abbas et al. [13] denoted that technological developments can reduce the negative effects of these projects on the environment. Thus, it is possible for renewable energy projects to be more sustainable.

Qualified personnel should also be employed for renewable energy transition process. Bai et al. [14] and Chetty et al. [15] demonstrated that qualified personnel also provide support for effective planning and project management. This allows renewable energy projects to be more successful. Moreover, Sillak [16] identified that qualified personnel also assist in the development of new technologies. The application of current technologies is of vital importance to ensure the effectiveness of renewable energy projects. Therefore, employing competent personnel enables this technology to be applied more easily and successfully. In addition, Hwang [17] indicated that qualified personnel also assist in the timely resolution of possible technical malfunctions. Thus, it will be much easier to increase the efficiency of the process.

Finding effective financial resources has a critical role in increasing the efficiency of the renewable energy transition process. One of the biggest disadvantages of renewable energy projects is the long payback period [18]. Similarly, high initial investment costs are another issue that reduces the effectiveness of this process. Zeraibi et al. [19] concluded that effective financial resources provide the capital required for these projects. In addition, Bhattarai et al. [20] determined that effective financial resources can accelerate the research and development of renewable energy technologies. This situation significantly helps to achieve technological progress in these projects. Moreover, Siddik et al. [21] showed that it is important to have sufficient financial resources for the effective risk management of renewable energy projects. Thanks to the timely provision of these resources, businesses can minimize the price increase problem caused by reasons such as inflation and exchange rate increase [22].

The literature review results indicate that renewable energy transition is necessary for the sustainable development of the countries. Hence, necessary actions should be taken to make improvements to the determinants of this situation. However, making improvements leads to cost increase in this process. Because of this issue, it is not optimal to improve lots of different items at the same time. Thus, a priority analysis in this framework is quite necessary. Nevertheless, in the literature, there are limited studies that focused on this issue. Therefore, this situation can be accepted as the main missing part in the literature regarding this subject. To satisfy this need, a priority analysis is conducted for renewable energy transition.

3. Methodology

The details of the methods given in the proposed model are explained in the following subsections.

3.1 Spherical Fuzzy TOP-DEMATEL

DEMATEL is a multi-criteria decision-making method that weighs the criteria, considering the causality between these indicators. As it is used with different fuzzy numbers, some of its steps can be updated and discussed in the literature [23]. The Spherical fuzzy TOP-DEMATEL method is the version in which both current fuzzy numbers are used, and the weight calculation is updated. The steps of this new method are provided as follows [24].

First, opinions are taken from experts about the criteria evaluations and converted into fuzzy numbers by using the values in Table 1. In this context, μ is a membership value, η is a non-membership value and υ is a hesitancy value of a fuzzy number [25].

Table 1
Linguistic Variable

Scales	μ	η	υ
4	,85	,15	,45
3	,6	,2	,35
2	,35	,25	,25
1	0	,3	,15
0	0	0	0

A matrix of expert opinions is created. The matrix is shown by Equation (1).

$$D^i = \begin{bmatrix} (0,0,0) & \cdots & (\mu_{1n}^i, \eta_{1n}^i, \nu_{1n}^i) \\ \vdots & \ddots & \vdots \\ (\mu_{n1}^i, \eta_{n1}^i, \nu_{n1}^i) & \cdots & (0,0,0) \end{bmatrix} \tag{1}$$

The decision matrix (D) is formed by taking the average of the expert opinions using Equation (2). The decision matrix is shown by Equation (3).

$$SFWAM_W(\widetilde{D}_1, \widetilde{D}_2, \dots \widetilde{D}_k) =$$

$$\left\{ \left[1 - \prod_{i=1}^{k} (1 - \mu_{D_i}^2)^{\frac{1}{k}} \right]^{\frac{1}{2}}, \prod_{i=1}^{k} \eta_{D_i}^{\frac{1}{k}}, \left[\prod_{i=1}^{k} (1 - \mu_{D_i}^2)^{\frac{1}{k}} - \prod_{i=1}^{k} (1 - \mu_{D_i}^2 - \nu_{D_i}^2)^{\frac{1}{k}} \right]^{\frac{1}{2}} \right\} \tag{2}$$

where *k* is the number of experts.

$$D = \begin{bmatrix} 0 & \cdots & (\mu_{1n}^d, \eta_{1n}^d, \nu_{1n}^d) \\ \vdots & \ddots & \vdots \\ (\mu_{n1}^d, \eta_{n1}^d, \nu_{n1}^d) & \cdots & 0 \end{bmatrix} \tag{3}$$

After, three separate submatrices are created for each component in spherical fuzzy numbers. Then, each submatrix is normalized with Equations (4) and (5).

$$X = sD \tag{4}$$

$$s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n}|d_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n}|d_{ij}|}\right] \tag{5}$$

Normalized submatrices are given by Equation (6).

$$X^{\mu} = \begin{bmatrix} 0 & \cdots & \mu_{1n} \\ \vdots & \ddots & \vdots \\ \mu_{n1} & \cdots & 0 \end{bmatrix} \quad X^{\eta} = \begin{bmatrix} 0 & \cdots & \eta_{1n} \\ \vdots & \ddots & \vdots \\ \eta_{n1} & \cdots & 0 \end{bmatrix} \quad X^{\nu} = \begin{bmatrix} 0 & \cdots & \nu_{1n} \\ \vdots & \ddots & \vdots \\ \nu_{n1} & \cdots & 0 \end{bmatrix} \tag{6}$$

Using Equation (7), the total relationship matrices (*T*) are calculated over each submatrix. The calculated submatrices are then applied with Euclidean normalization.

$$T = X * (1 - X)^{-1} \tag{7}$$

Combined relationship matrix ($\tilde{T}$) is generated by Equation (8).

$$\tilde{T} = \begin{bmatrix} (\mu_{11}^T, \eta_{11}^T, \nu_{11}^T) & \cdots & (\mu_{1n}^T, \eta_{1n}^T, \nu_{1n}^T) \\ \vdots & \ddots & \vdots \\ (\mu_{n1}^T, \eta_{n1}^T, \nu_{n1}^T) & \cdots & (\mu_{nn}^T, \eta_{nn}^T, \nu_{nn}^T) \end{bmatrix} \tag{8}$$

The score function is calculated with the help of Equation (9). This score is used for the defuzzification process.

$$Score = \mu^2 - \eta^2 - \nu^2 \tag{9}$$

Final, weights (*W*) are obtained using Equation (10)-(16).

$$C^{*}{}_{j} = \sqrt{\sum_{i=1}^{n}\left(t_i - \max_j t_i\right)^2} \quad j = 1,2,..n \tag{10}$$

$$C^{-}{}_{j} = \sqrt{\sum_{i=1}^{n}\left(t_i - \min_j t_i\right)^2} \quad j = 1,2,..n \tag{11}$$

$$R^{*}{}_{i} = \sqrt{\sum_{j=1}^{n}\left(t_j - \max_i t_j\right)^2} \quad i = 1,2,..n \tag{12}$$

$$R^{-}{}_{i} = \sqrt{\sum_{j=1}^{n}\left(t_j - \max_i t_j\right)^2} \quad i = 1,2,..n \tag{13}$$

$$S_i^{*} = C_i^{*} + R_i^{*} \tag{14}$$

$$S_i^{-} = C_i^{-} + R_i^{-} \tag{15}$$

$$W_i = \frac{S_i^{-}}{S_i^{-} + S_i^{*}} \tag{16}$$

3.2 Spherical Fuzzy RATGOS

The RATGOS method is a multi-criteria decision-making method used for ranking alternatives. This technique is based on the geometric mean of the similarity ratios of the alternatives to the optimal value [26]. First, expert opinions are taken on a seven-point scale. Then, it is converted into the fuzzy numbers as detailed in Table 2.

Table 2
Linguistic Variables for Ranking

Scales	μ	η	v
1	.1	.9	0
2	.2	.8	.1
3	.3	.7	.2
4	.4	.6	.3
5	.5	.5	.4
6	.6	.4	.3
7	.7	.3	.2

Then, using Equation (2), the average of the expert opinions (*Z*) is obtained. In the *Z* matrix, the optimal value is determined for each criterion. Equations (17) and (18) are used for this purpose.

$$optimal = \{(\mu, \eta, v) | \max\ (Score(Z_i)\}\ for\ benefit\ criteria \quad (17)$$

$$optimal = \{(\mu, \eta, v) | \min\ (Score(Z_i)\}\ for\ cost\ criteria \quad (18)$$

In this process, score (Z_i) is the score function of the spherical fuzzy Z_i number and is calculated using Equation (9). Then, using the *Z* matrix, the defuzzied matrix (*F*) is obtained. By dividing *F* matrix values to the optimal value, the similarity matrix to the optimal value (*B*) is obtained. Equations (19) and (20) are used in this process.

$$b_{ij} = \frac{f_{ij}}{Score(optimal_j)} \qquad i = 1,2, \dots n, j = 1,2, \dots, m\ \ for\ benefit\ criteria \quad (19)$$

$$b_{ij} = \frac{Score(optimal_j)}{f_{ij}} \qquad i = 1,2, \dots n, j = 1,2, \dots, m\ \ for\ cost\ criteria \quad (20)$$

With Equation (21), the weighted normalization matrix (*N*) is obtained by multiplying the *B* matrix with the weights (*W*) of the criteria.

$$N = B * W \quad (21)$$

Since the values of the *N* matrix have negative values due to the score function, the geometric mean (*G*) is calculated on a row basis by Equation (22). Thus, the average similarity ratios can be calculated.

$$G_i = \sqrt{\prod_{i=1}^{n} (1 + n_{ij}) - 1} \quad (22)$$

G values are ranked. The highest value is considered as the most suitable alternative.

4. Analysis Results

This part consists of weighting the criteria and ranking the alternatives. The results are given in the following subsections.

4.1 Weighting the Items with Spherical Fuzzy TOP-DEMATEL

According to the results of literature review, five different factors are selected as indicators of effective renewable energy transition that are legal regulations (Legal), technological development (Technology), qualified personnel (Qualified), effective financial sources (Finance) and competitive pricing (Price). With the help of legal regulations, the security to the renewable energy projects can be increased. This situation helps to increase these investments. On the other side, technological development has a positive contribution to increase the cost effectiveness of these projects. Owing to high profitability opportunity, investors can focus on this situation. Moreover, renewable energy investments are very complex projects. Thus, to minimize any problems in this process, companies should employ qualified personnel. Additionally, to increase the effectiveness of renewable energy transition, necessary financial sources should be found. Finally, companies should provide a reasonable price so that competitive power of these projects can be increased.

Evaluations are taken from three different experts. Two of these people are professors. They have a lot of publications related to the renewable energy investments, energy transition, energy independence and energy finance. On the other side, the third expert has more than 26 years of working experience. He joined many different projects, such as solar energy investments, generation of wind energy projects, strategies to minimize carbon emissions. Expert opinions are provided in Table 3.

Table 3
Expert Opinions

			Expert 1		
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	0	1	2	1	2
Technology	4	0	4	3	4
Qualified	2	1	0	1	3
Finance	3	2	3	0	4
Pricing	2	1	3	1	0
			Expert 2		
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	0	2	2	1	3
Technology	3	0	4	4	4
Qualified	2	2	0	3	2
Finance	2	1	1	0	3
Pricing	1	1	2	1	0
			Expert 3		
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	0	2	2	2	2
Technology	4	0	4	2	3
Qualified	1	1	0	2	2
Finance	3	3	4	0	3
Pricing	1	1	2	1	0

Expert opinions are converted into linguistic expression equivalents as given in Table 1. Then, decision matrix is created by using Equation (2). Decision matrix is demonstrated by Table 4.

Table 4
Decision Matrix

	Legal			**Technology**			**Qualified**			**Qualified**			**Pricing**		
Legal	.00	.00	.00	.29	.27	.15	.35	.25	.25	.21	.28	.15	.46	.23	.25
Technology	.80	.17	.48	.00	.00	.00	.85	.15	.45	.68	.20	.38	.80	.17	.48
Qualified	.29	.27	.25	.21	.28	.15	.00	.00	.00	.42	.25	.15	.46	.23	.35
Finance	.54	.22	.35	.42	.25	.25	.66	.21	.39	.00	.00	.00	.72	.18	.49
Pricing	.21	.28	.25	.00	.30	.15	.46	.23	.35	.00	.30	.15	.00	.00	.00

Next, submatrices are created. Each matrix is normalized with Equations (4) and (5). Normalized submatrices are denoted in Table 5.

Table 5
Normalized Submatrices

M	**Legal**	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	.0000	.0925	.1121	.0661	.1469
Technology	.2550	.0000	.2723	.2177	.2550
Qualified	.0925	.0661	.0000	.1340	.1469
Finance	.1722	.1340	.2120	.0000	.2300
Pricing	.0661	.0000	.1469	.0000	.0000
$\boldsymbol{\eta}$	**Legal**	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	.0000	.2384	.2243	.2533	.2083
Technology	.1481	.0000	.1346	.1757	.1481
Qualified	.2384	.2533	.0000	.2213	.2083
Finance	.1933	.2213	.1867	.0000	.1631
Pricing	.2533	.2692	.2083	.2692	.0000
$\boldsymbol{\upsilon}$	**Legal**	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	.0000	.0837	.1394	.0837	.1402
Technology	.2683	.0000	.2508	.2126	.2683
Qualified	.1395	.0837	.0000	.0844	.1964
Finance	.1963	.1407	.2153	.0000	.2739
Pricing	.1395	.0836	.1964	.0836	.0000

Then, total relationship matrices are created by Equation (7). On the other side, It is defuzified by Equation (9). The defuzzified T matrix is indicated in Table 6.

Table 6
Defuzzified T Matrix

	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Legal	-.1819	-.16635	-.26008	-.26205	-.234
Technology	-.00348	-.11203	-.02238	-.01783	-.07137
Qualified	-.26944	-.23113	-.18353	-.1633	-.26668
Finance	-.16835	-.0785	-.16995	-.16338	-.19176
Pricing	-.37683	-.41199	-.36406	-.39344	-.23619

Finally, criteria weights are calculated with Equation (10)-(16). The criteria weights are demonstrated in Table 7.

Table 7
Criteria Weights

Criteria	Weights	Rank
Legal	.197601	4
Technology	.242403	1
Qualified	.199165	3
Finance	.199578	2
Pricing	.161253	5

Table 7 indicates that technological development has the most important role for the success of renewable energy transition due to the greatest weight (0.242403). Similar to this situation, finding effective financial source plays also a significant role in this condition with the weight of 0.199578. Employing qualified personnel is on the third rank in this context. However, effective legal regulation and providing competitive pricing have the lower weights by comparing with other indicators. Hence, it is seen that companies should mainly focus on technological development. With the help of this situation, it can be possible to generate electricity from renewable energy with a more reasonable cost. This cost effectiveness provides an opportunity to increase the profitability of the projects. This situation can be very useful to attract the attention of the investors for renewable energy projects. On the other hand, it is necessary to reach the necessary financial resources for the successful implementation of the renewable energy transition process. This will contribute to the effective cost management of the projects. Thus, the profitability of the projects will be increased, and this will attract the attention of investors.

4.2 Ranking BRICS Countries with Spherical Fuzzy RATGOS

In the second part of the study, alternatives are ranked. In this context, BRICS countries (Brazil, Russia, India, China, South Africa) are selected as alternatives. For this purpose, opinions of three different experts are provided. Expert opinions are denoted in Table 8.

Table 8
Experts Opinions for Ranking

	Expert1				
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Brazil	3	2	2	2	1
Russia	3	6	5	4	5
India	2	1	1	2	2
China	7	7	7	7	7
SAfrica	1	1	1	2	2
	Expert2				
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Brazil	2	4	1	2	3
Russia	3	4	6	6	7
India	2	2	1	3	1
China	6	7	6	7	6
SAfrica	2	1	3	2	2
	Expert3				
	Legal	**Technology**	**Qualified**	**Finance**	**Pricing**
Brazil	2	1	1	2	3
Russia	4	5	5	4	5

India	2	3	1	2	2
China	5	7	5	7	6
SAfrica	2	1	1	1	2

Expert opinions are converted into fuzzy numbers in the following stage. After that, the average of the expert opinions is taken with Equation (2). The decision matrix (Z) obtained by the average of expert opinions is given in Table 9.

Table 9
Decision Matrix (Z)

	Legal			Technology			Qualified			Finance			Pricing		
Brazil	.24	.77	.20	.27	.76	.10	.14	.87	.10	.20	.80	.10	.25	.76	.00
Russia	.34	.66	.20	.51	.49	.30	.54	.46	.40	.48	.52	.30	.58	.42	.40
India	.20	.80	.10	.22	.80	.00	.10	.90	.00	.24	.77	.10	.17	.83	.10
China	.61	.39	.20	.70	.30	.20	.61	.39	.20	.70	.30	.20	.64	.36	.20
SAfrica	.17	.83	.00	.10	.90	.00	.19	.83	.00	.17	.83	.10	.20	.80	.10

Then, using the score function, the optimal values are determined. The similarity matrix is calculated by Equations (19) and (20). Similarity matrix is given in Table 10.

Table 10
Similarity Matrix

	Legal	Technology	Qualified	Finance	Pricing
Brazil	-3.15	-1.41	-4.09	-1.69	-2.20
Russia	-2.04	-0.20	-0.48	-0.37	0.00
India	-3.38	-1.63	-4.43	-1.50	-2.87
China	1.00	1.00	1.00	1.00	1.00
SAfrica	-3.67	-2.22	-3.59	-1.87	-2.60

A weighted normalized matrix is obtained by Equation (21). The weights used in this process are the criteria weights obtained in the Spherical Fuzzy TOP-DEMATEL method. Finally, G values are calculated using Equation (22). Weighted normalized matrix and G values are demonstrated in Table 11.

Table 11
Weighted Normalize Matrix and G Values

	Legal	Technology	Qualified	Finance	Pricing	G	Rank
Brazil	-.62	-.34	-.81	-.34	-.35	-.54	3
Russia	-.40	-.05	-.10	-.07	.00	-.14	2
India	-.67	-.39	-.88	-.30	-.46	-.61	5
China	.20	.24	.20	.20	.16	.20	1
SAfrica	-.72	-.54	-.71	-.37	-.42	-.58	4

Considering the G values, it is seen that the best alternative is China because it has the highest G value. Similarly, Russia is in second place for this situation. On the other side, it is also concluded that South Africa and India are less successful in renewable energy transition in comparing with other BRICS countries.

5. Discussion and Conclusion

An evaluation is conducted regarding renewable energy transition. In this scope, five criteria are selected based on the literature review results. Spherical fuzzy TOP-DEMATEL methodology is considered to compute the weights of these indicators. Secondly, alternatives are ranked with Spherical fuzzy RATGOS. In this context, BRICS countries (Brazil, Russia, India, China, South Africa) are selected as alternatives. It is concluded that technological development plays the most important role for the success of renewable energy transition. Similarly, finding effective financial source is also very important in this condition. Employing qualified personnel is on the third rank in this context. However, effective legal regulation and providing competitive pricing have the lower weights by comparing with other indicators. The ranking results also indicate that China and Russia are the most successful countries regarding renewable energy transition. On the other side, it is also concluded that South Africa and India are less successful in renewable energy transition in comparing with other BRICS countries.

It is understood that technological development plays a critical role in increasing the efficiency of the renewable energy transition process. Thanks to the use of up-to-date technology, it is possible to use energy resources more efficiently. This contributes to the reduction of the efficiency of the projects. This is very important to increase their profitability in investments. Since profitable investments may be preferred more by investors, this helps to ensure the sustainability of the projects. Afshan et al. [27] discussed that technological developments are also necessary for the efficiency of energy storage processes. Variations in climatic conditions cause irregularities in the energy production process. Wang et al. [28] identified that thanks to the efficient energy storage processes, it is possible to solve this problem. Similarly, the availability of effective financial resources has a critical role in increasing the efficiency of the renewable energy transition process. Bouyghrissi et al. [29] mentioned that due to the high initial cost of renewable energy projects, effective financial resources must be accessible. This ensures that the capital needed for the renewable energy transition can be found [30].

Generating RATGOS is the main novelty of this manuscript. Scholars criticized similar techniques in the literature due to some reasons. Due to this issue, RATGOS approach is proposed while considering geometric mean in proportional concepts. Additionally, the most critical determinants of renewable energy transition can be presented with the help of the priority analysis. This situation helps the investors focus on more important factors. The main limitation of this study is making examination for only BRICS countries. Renewable energy transition also plays a critical role for developed economies. Thus, in the following studies, a new evaluation can also be conducted for developed countries.

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Conflicts of Interest
The authors declare no conflicts of interest.

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