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Making Risk Evaluation for The Renewable Energy Investments in The Telecommunications Sector with SF TOP-DEMATEL Methodology

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ABSTRACT

Energy has an important role in the telecommunications sector. Therefore, it would be advantageous for telecommunication enterprises to produce their own energy. One of the best ways for these companies to produce their energy is renewable energy. However, there are some risks for them to make renewable energy investments. It is vital to manage these risks without incurring high costs. Accordingly, the purpose of this study is to conduct a priority analysis of the critical risks of renewable energy investment in the telecommunications sector. In this context, five different risks are analysed with the SF TOP DEMATEL method. As a result of the analysis, the provision of uninterrupted energy is found as the most critical risk with the weight of 0.2093. Other important risks are defined as cost and updateability. To meet the energy needs of the telecommunications sector by making renewable energy investment, it would be appropriate to take action to ensure an uninterrupted energy supply. For this purpose, hybrid energy models and energy storage technologies are reasonable solutions.

Keywords: clean energy, renewable energy, risk evaluation, telecommunications sector, TOP-DEMATEL.

JEL Classification: Q40, C02, C61

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1. INTRODUCTION

Renewable energy investments are key to the social and economic development of countries. Through energy investments, countries will be able to produce their own energy. In other words, renewable energy investments strongly contribute to the development of energy independence of countries. In addition to the mentioned point, renewable energy investments are also very important for reducing the carbon emission problem. Carbon emissions are considered to be one of the main causes of global warming as they cause many serious problems such as air pollution (Yan et al., 2022). Therefore, one of the most important issues in combating carbon emissions is that the source of electricity generation should not be fossil fuels. Instead, obtaining electricity through renewable energy sources can significantly reduce the amount of carbon emitted into the atmosphere. On the other hand, renewable energy projects significantly reduce the current account deficit problem of countries. Countries that can produce their own energy will not have to import their electricity needs from other countries. Since the amount of imports decreases, this is a positive situation for countries (Ali et al., 2022).

Renewable energy policies are important for many sectors. One of the sectors that needs the most attention in this process is the telecommunications sector. The main reason for this is that the telecommunications sector uses a very wide internet network across the country. Therefore, there is a significant energy need in the telecommunications sector. Currently, energy is supplied from fossil fuels. For this reason, the telecommunications sector is also known to contribute to the carbon emission problem (Napolitano, 2023). Therefore, it is important to realize the energy transition process for the telecommunications sector. In this context, it would be appropriate to take necessary actions to increase the use of renewable energy in this sector. The risks of renewable energy investments in the telecommunications sector should also be reduced.

It can be said that renewable energy investments in the telecommunications sector involve many risks. One of the most important risks is energy interruption. Renewable energy sources can be affected by different climatic conditions. In this context, while more energy can be produced than necessary in some parts of the day, in other cases, the amount of energy supplied cannot meet the need. In cases where the need cannot be met, a power outage may occur. On the other hand, considering that the telecommunications sector serves the citizens of the whole country, energy interruption is an unacceptable situation (Cui et al., 2023). In addition, exchange rate risk is another factor to be considered for renewable energy investments in the telecommunications sector. A rising exchange rate increases the cost of raw materials in renewable energy projects. If the increased costs cannot be managed effectively, it will put the sustainability of the projects at risk (Ibrahim et al., 2022). Finally, technological risks also affect the performance of renewable energy projects in the telecommunications industry. Hence, failure to utilize current technology or disruptions in existing technology can significantly reduce the effectiveness of these projects.

In order to increase the effectiveness of renewable energy investments to be made in the telecommunications sector, the mentioned risks should be managed correctly. In this framework, it is important to take the necessary measures and minimize the negative impacts that may arise due to these risks. On the other hand, the most important disadvantage of this process is that the measures to be taken to manage risks increase costs. In other words, the measures taken to properly manage the risks of these investments in the telecommunications sector also cause the costs of these enterprises to increase. Therefore, instead of focusing on all problems in the risk management process, it would be a more accurate and more efficient strategy to identify the most important ones and take measures accordingly. Therefore, there is a need for a priority analysis to determine the most important risks.

The contributions of this study to the literature are given below. (i) It will help to identify possible risks for the use of renewable energy in the telecommunications sector. By ranking these risks according to their importance, it will enable the implementation of prioritized strategies. (ii) Global fuzzy numbers are used in the analysis. In this way, it can be stated that the results are more appropriate. (iii) The multi-criteria decision-making method used in the research also shows the superiority of the model.

The next section contains the literature review. The methodology is given in the third section. The fourth section presents the results of the analysis. Finally, the discussion and conclusion section is defined.

2. LITERATURE REVIEW

The telecommunications sector provides services such as internet, communication, and data transmission (Al-Dujaili et al., 2023). Accordingly, uninterrupted energy supply is crucial for telecommunication services (Skopljiak et al., 2023). In the telecommunications sector, communication breakdowns and data loss may occur if uninterrupted energy is not provided. In addition, it may cause service disruptions and security risks (Selim et al., 2023). The energy needs in the telecommunications sector can be met with renewable resources. However, one of the most significant risks of renewable energy sources is fluctuations in energy production (Kojima et al., 2023). Hybrid energy models such as solar and wind can be used to avoid this risk (Gao et al., 2023). Ali et al. (2023) investigated the feasibility of solar home systems to develop the industry in Pakistan. The study results indicate that the state should provide uninterrupted energy services to its citizens. Khan and Maieed (2023) examine the relationship between energy poverty and the importance of financial sector development in developing countries. The importance of uninterrupted energy supply for this development is emphasized. Daneshvar et al. (2023) and Acar et al. (2023) mention the importance of uninterrupted energy supply.

Environmental factors are very important for the success of the telecommunications sector (Sheveleva and Avdeeva, 2023). To meet customer expectations, it is necessary to be sensitive to the environment (Onngam and Charoensukmongkol, 2023). Meeting customer expectations is also important in an increasingly competitive environment (Kathuria and Rana, 2023). An important way to consider environmental factors is the use of clean energy. By using clean energy, the carbon footprint can be reduced (Zhao et al., 2023). In this way, both the environment and customer expectations are met. However, there are some risks in terms of environmental factors when investing in renewable energy. One of these risks is the damage to the ecosystem if the hydroelectric power generation process is not well managed (Yin et al., 2023). Pata et al. (2023) examined the relationship between renewable energy types, ecological quality improvement, and economic growth. It is stated that environmental factors should be taken into account in investments in renewable energy. Zhironkin et al. (2023) analyze the specific characteristics and development factors of renewable energy. The study emphasizes the importance of the environmental factor in the transition to renewable energy. Zhang et al. (2023) and Dorahaki et al. (2023) draw attention to environmental risks in the use of clean energy.

Efficiency is an important factor for the sustainability of telecommunication businesses (Abbott and Cohen, 2023). Many strategies can be mentioned to ensure efficiency. These strategies include employee training, ensuring customer satisfaction, and environmental awareness. In addition to these, the use of renewable energy is an important way to ensure efficiency for telecommunication businesses (Siddik et al., 2023). Because energy is one of the most important elements for ensuring the sustainability of the telecommunications sector. Therefore, it will provide a competitive advantage for enterprises with such energy use to produce their energy (Almutairi et al., 2023). Yan et al. (2023) examined the role of energy efficiency, renewable energy, and financial development in environmental improvement. The results of the study in developing countries show that the use of renewable energy is important for efficiency. Shah et al. (2023) investigates the role of energy consumption and carbon emissions in achieving energy efficiency. The study, which was conducted using data from G20 countries, states that one of the best ways to achieve efficiency is to use renewable energy. Zhang et al. (2023) and Awosusi et al. (2023) argue that the use of clean energy is a good way to achieve efficiency.

Another critical factor affecting telecommunications businesses is cost (Skoufis et al., 2023). There are many cost elements for these businesses. However, one of the biggest cost elements is energy. Accordingly, telecommunication businesses need to achieve cost savings. One of the best options to achieve cost savings is to meet energy needs with renewable energy sources (Rehman et al., 2023). It is also important for businesses to generate their energy to avoid being affected by fluctuations in energy prices. However, meeting energy needs with renewable resources also has some risks. First of all, the initial investment cost of renewable energy investments is quite high. In addition, seasonal fluctuations in production may occur. Osman et al. (2023) examined the costs and environmental impact of renewable energy under changing climatic conditions. It is stated that cost is an important factor for renewable energy sources. Lu et al. (2023) and Alawad et al. (2023) state that the cost should be well calculated for the use of clean energy. Ye et al. (2023) and Alsagr (2023) underline that cost should be considered in renewable energy investments.

The results of the literature review are as follows. Energy is used intensively in the telecommunications sector. Ensuring the sustainability of the sector is important for economic development. Accordingly, telecommunication enterprises need to meet their energy needs. Therefore, renewable energy is a good alternative for meeting energy needs. However, studies on the issues affecting this process are quite limited in the literature. It would be appropriate to conduct a prioritization study for this situation, which is missing in the literature. In this direction, it is aimed to develop a strategy for the barriers to the use of renewable energy in the telecommunications sector

3. METHODOLOGY

The DEMATEL method is a method used for weighting the criteria. The main feature of this method is that it takes into account causality between criteria. If the decision matrix is symmetrical, a problem occurs in the weighting step of the classical DEMATEL methods. Therefore, the DEMATEL method is being developed in the literature. The TOP-DEMATEL method is one of them. The use of this developed method with spherical fuzzy numbers has recently been introduced to the literature. The steps of this method are as follows.

Firstly, Criterion evaluations are received from experts. Experts consist of people who work in the relevant field and have at least 10 years of experience. Additionally, the experts selected are academics who have published in important journals. Then, translated to spherical fuzzy numbers in Table 1. Where μ, η and υ are membership value, non-membership value and hesitancy value, respectively.

Table 1. Linguistic Variable

Scale	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 is created from experts' opinions. The matrix is given with Equation (1).

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

The decision matrix (D) is created by taking the average of the expert opinions with Equation (2). The decision matrix is given with Equation (3). The weights in Equation (2) are taken as 1/k.

$$SFWAM_W(\widetilde{D}_1, \widetilde{D}_2, \ldots \widetilde{D}_k) = \left\{ \left[1 - \prod_{i=1}^{k} (1 - \mu_{D_i}^2)^{\frac{1}{k}}\right]^{\frac{1}{2}}, \prod_{i=1}^{k} \eta_{D_i}^{\frac{1}{k}}, \left[\prod_{i=1}^{k} (1 - \mu_{D_i}^2)^{\frac{1}{k}} - \prod_{i=1}^{k} (1 - \mu_{D_i}^2 - \nu_{D_i}^2)^{\frac{1}{k}}\right]^{\frac{1}{2}} \right\} \quad (2)$$

Where k is the number of experts.

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

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

$$X=sD \quad (4)$$

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

Normalized submatrices are given with Equation (6).

$$X^{\mu}=\begin{bmatrix} 0 & \cdots & \mu_{1n} \\ \vdots & \ddots & \vdots \\ \mu_{n1} & \cdots & 0 \end{bmatrix} X^{\eta}=\begin{bmatrix} 0 & \cdots & \eta_{1n} \\ \vdots & \ddots & \vdots \\ \eta_{n1} & \cdots & 0 \end{bmatrix} X^{v}=\begin{bmatrix} 0 & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{n1} & \cdots & 0 \end{bmatrix} \quad (6)$$

With the help of Equation (7), the total relationship matrices (T) are calculated over each submatrix. Then, the calculated submatrices are applied by Euclidean normalization.

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

The calculated sub-total relationship matrices are combined and the spherical fuzzy total relationship matrix ($\tilde{T}$) is obtained.

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

The score function is calculated by Equation (9), the spherical fuzzy total relationship matrix. This score is used for the defuzziefied method.

$$Score=\mu^2-\eta^2-v^2 \quad (9)$$

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

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

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

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

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

$$S_i^{*}=C_i^{*}+R_i^{*} \quad (14)$$

$$S_i^{-}=C_i^{-}+R_i^{-} \quad (15)$$

$$W_i=\frac{S_i^{-}}{S_i^{-}+S_i^{*}} \quad (16)$$

4. EMPIRICAL RESULTS AND DISCUSSION

The results of the analysis are included in this section. First, opinions are obtained from three different experts. Expert opinions are given in Table 2.

Table 2. Expert opinions

Expert 1					
	Cost	**Uninterrupted**	**Productivity**	**Environmental Factors**	**Updateability**
Cost	0	2	3	1	3
Uninterrupted	2	0	3	2	3
Productivity	3	3	0	2	4
Environmental Factors	1	2	4	0	3
Updateability	4	4	3	4	0
Expert 2					
	Cost	**Uninterrupted**	**Productivity**	**Environmental Factors**	**Updateability**
Cost	0	3	1	1	3
Uninterrupted	4	0	3	4	4
Productivity	3	3	0	2	2
Environmental Factors	2	3	1	0	2
Updateability	3	4	3	4	0
Expert 3					
	Cost	**Uninterrupted**	**Productivity**	**Environmental Factors**	**Updateability**
Cost	0	1	1	2	2
Uninterrupted	4	0	3	3	4
Productivity	3	3	0	3	4
Environmental Factors	4	4	4	0	3
Updateability	1	3	1	3	0

Decision matrix is created by Equation (2). The matrix is given in Table 3.

Table 3. Decision matrix

	Cost			**Uninterrupted**			**Productivity**			**Environmental Factors**			**Updateability**		
Cost	0,00	0,00	0,00	0,42	0,25	0,25	0,37	0,26	0,35	0,21	0,28	0,15	0,54	0,22	0,35
Uninterrupted	0,77	0,18	0,27	0,00	0,00	0,00	0,60	0,20	0,35	0,68	0,20	0,27	0,80	0,17	0,37
Productivity	0,60	0,20	0,35	0,60	0,20	0,35	0,00	0,00	0,00	0,46	0,23	0,25	0,77	0,18	0,50
Environmental Factors	0,61	0,22	0,16	0,68	0,20	0,27	0,76	0,19	0,51	0,00	0,00	0,00	0,54	0,22	0,35
Updateability	0,66	0,21	0,51	0,80	0,17	0,48	0,51	0,23	0,35	0,80	0,17	0,48	0,00	0,00	0,00

Then, three sub-matrices are obtained from decision matrix. So, three sub-matrices are normalized with help of Equation (4) and (5). Normalized sub-matrices are shown in Table 4.

Table 4. Normalized sub-matrices

X^{μ}	Cost	Uninterrupted	Productivity	Environmental Factors	Updateability
Cost	0,0000	0,1470	0,1307	0,0726	0,1889
Uninterrupted	0,2706	0,0000	0,2109	0,2388	0,2797
Productivity	0,2109	0,2109	0,0000	0,1611	0,2706
Environmental Factors	0,2154	0,2388	0,2664	0,0000	0,1889
Updateability	0,2326	0,2797	0,1783	0,2797	0,0000
X^{η}	**Cost**	**Uninterrupted**	**Productivity**	**Environmental Factors**	**Updateability**
Cost	0,0000	0,2450	0,2604	0,2805	0,2141
Uninterrupted	0,1767	0,0000	0,1987	0,1945	0,1640
Productivity	0,1987	0,1987	0,0000	0,2306	0,1767
Environmental Factors	0,2226	0,1945	0,1878	0,0000	0,2141
Updateability	0,2067	0,1640	0,2275	0,1640	0,0000
X^{v}	**Cost**	**Uninterrupted**	**Productivity**	**Environmental Factors**	**Updateability**
Cost	0,0000	0,1286	0,1783	0,0765	0,1794
Uninterrupted	0,1367	0,0000	0,0000	0,1368	0,1871
Productivity	0,1783	0,1783	0,2600	0,1281	0,2553
Environmental Factors	0,0839	0,1368	0,1805	0,0000	0,1794
Updateability	0,2623	0,2451	0,0000	0,2451	0,0000

Total relationship matrix (T) is created by Equation (7) and (9). Then, weights of criteria are calculated with Equation (10)-(16). S*, S- and W values are shown in Table 5.

Table 5. S*, S^- and W values

Criteria	S*	S^-	W
Cost	0,7871	4,9546	0,2087
Uninterrupted	0,7671	4,9369	0,2093
Productivity	0,8821	3,3361	0,1913
Environmental Factors	0,6864	2,6954	0,1927
Updateability	0,8558	3,8651	0,1980

According to Table 5, uninterrupted is most important criteria. Because weight of these criteria is 0.2093. The second important criterion is cost with 0.2087.

5. CONCLUSION

The study aims to determine the priority analysis of possible risks for the use of renewable energy in the telecommunications sector. For this purpose, the SF TOP-DEMATEL method is used. With this analysis method, 5 different criteria affecting the use of renewable energy in the telecommunications sector are taken into consideration. The criterion that affects the process in question is found to be the provision of uninterrupted energy with a value of 0.2093. Cost and environmental factors are other important criteria affecting the use of renewable energy in the telecommunications sector.

Providing uninterrupted energy is very important for the telecommunications sector. Ensuring the sustainability of the telecommunications sector is directly related to uninterrupted energy supply. In addition, data losses and customer dissatisfaction are likely to occur in the absence of uninterrupted power supply. Amole et al. (2021) investigate the use of renewable energy for sustainable telecommunication systems in Nigeria. It is stated that the design should be done correctly to provide the energy needed with renewable resources. Napolitano (2023) analyses the role of artificial intelligence and advanced telecommunications in the transition to smart cities. The importance of clean energy sources is emphasized to achieve the goal. Silva et al.

(2020) examine the battery energy management process of a telecommunication company. It emphasizes how important backup batteries are for telecommunication companies. This, the importance of renewable energy for service continuity is also mentioned.

Balmer et al. (2020) investigate the applications of artificial intelligence in the telecommunications sector. It also mentions the importance of renewable energy for the telecommunications sector. Khalid et al. (2023) discuss the need for telecommunications in the delivery of public services. Utilities should consider telecommunication infrastructures when trying to achieve clean energy targets. Chen (2022) debates whether the digital economy in China promotes clean energy development. It is stated that there is an important relationship between clean energy and the telecommunications sector. Crentsil et al. (2019) assesses energy poverty and influencing factors in Ghana. It is emphasized that as the level of energy deprivation increases, the use of telecommunications decreases. Yang et al. (2023) describe the impact of clean energy structure on CO2 and air pollutant emission reduction. It is indicated that the use of clean energy directly affects the telecommunications sector.

The main contribution of this study to the literature is to conduct a priority analysis to ensure that the energy used in the telecommunications sector can be provided by renewable resources. This provides an opportunity to implement effective strategies to meet the needs with clean energy. In addition, the effectiveness of the results is higher since the analysis is performed with global fuzzy numbers. However, the limitation of the study is that it was conducted with limited experts and is specific only to the telecommunications sector. Studies can be conducted for different sectors.

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