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A Dual-Stage Decision-Making Model for Overcoming Investment Barriers in Nuclear Energy Projects in Turkey

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ABSTRACT

Nuclear energy projects have many advantages. High energy efficiency is one of the most important advantages of this type of energy. With nuclear reactors, a very large amount of energy can be produced with a small amount of fuel. Low carbon emissions are another advantage of nuclear energy. Compared to fossil fuels, the carbon emissions that occur in obtaining energy from nuclear reactors are almost zero. Nuclear energy is also of vital importance for Turkey. The most fundamental reason for this is that Turkey is a country that is dependent on foreign energy. This situation negatively affects the country's current account deficit. The increasing current account deficit also makes the country's economy much more fragile. Nuclear energy increases energy supply security as a domestic energy source and reduces external dependency. The development of Turkey's nuclear energy investments is essential. For this process to be implemented successfully, measures must be taken to eliminate these difficulties. In this study, it is aimed to identify the most appropriate strategies for the development of Turkey's nuclear energy investments. Within this framework, a two-stage decision-making model is established. In the first part of the study, the importance weights of the selected criteria are calculated. In this process, the DEMATEL technique is taken into consideration. In the second part of the model, the aim is to determine the most appropriate investment strategies. To achieve this goal, a Rankin analysis is carried out using the TOPSIS technique. It is concluded that technological improvement is the most critical indicator to overcome the problems of nuclear energy investments. Financial issues and customer expectations are other essential items in this regard. However, organizational effectiveness has the lower weight in comparison with the other determinants. On the other side, it is identified that technological and operational development is the most critical strategy to minimize the negative impacts of the nuclear energy investments. Similarly, overcoming financing and economic challenges and improving regulation and policies are other critic issues for this situation.

1. Introduction

Nuclear energy is a type of energy obtained by releasing the energy in the atomic nucleus as a result of the reaction [1]. In this process, the nuclei of the atoms are divided by the effect of neutrons. A large amount of energy is released during this division. Elements with more nuclei such as uranium and plutonium are preferred to obtain more energy [2]. The important point in this process is that the reaction is carried out in a controlled manner. This allows a high amount of energy to be obtained. Otherwise, an uncontrolled reaction can cause a nuclear explosion. It is possible to talk about many advantages of nuclear energy [3]. High energy efficiency is one of the most important advantages of this type of energy. With nuclear reactors, a very large amount of energy can be produced with a small amount of fuel. Low carbon emissions are another advantage of nuclear energy [4]. Compared to fossil fuels, the carbon emissions that occur in obtaining energy from nuclear reactors are almost zero [5]. On the other hand, another advantage of nuclear reactors is the formation of continuous energy production. In other words, continuous energy that is not dependent on weather conditions can be provided [6]. However, nuclear energy also has some disadvantages. Nuclear reactors produce radioactive waste [7,8]. It is of critical importance that this waste is disposed of safely. Furthermore, nuclear energy also has security risks [9]. For example, the explosion in the Chernobyl nuclear reactor in 1986 caused both social and economic problems. Moreover, nuclear power plant installations are quite expensive and take a long time to complete.

Nuclear energy is also of vital importance for Turkey. The most fundamental reason for this is that Turkey is a country that is dependent on foreign energy [10]. In other words, Turkey meets a large portion of its energy needs by importing from other countries. This situation negatively affects the country's current account deficit. The increasing current account deficit also makes the country's economy much more fragile. Nuclear energy increases energy supply security as a domestic energy source and reduces external dependency [11]. With the help of this issue, it is possible to achieve the country's energy independence. On the other hand, energy demand in Turkey has been increasing significantly, especially in recent years. Energy demand is also increasing rapidly with Turkey's economic growth and population growth. Nuclear energy is a suitable base load energy source to meet this increase. In addition to them, nuclear energy is also necessary for Turkey to achieve its low carbon emission targets. Nuclear energy helps reduce carbon emissions caused by fossil fuels [12]. As can be seen, nuclear energy is necessary for Turkey in many ways. On the other hand, nuclear energy investments also have some difficulties. Nuclear power plant installations require large investments [13]. The high costs make the development of these projects difficult. Furthermore, it is important to store radioactive waste safely. Moreover, taking security measures for these projects helps the public to accept these projects more easily [14].

The development of Turkey's nuclear energy investments is essential. For this process to be implemented successfully, measures must be taken to eliminate these difficulties. In this context, a comprehensive analysis must be carried out, and the most appropriate investment strategy must be determined. However, there are limited studies on this subject in the literature. This situation increases the need for a new study. The aim of this study is to determine the most appropriate strategies for the development of Turkey's nuclear energy investments. In this context, a two-stage decision-making model is established. In the first part of the study, the importance weights of the selected criteria are calculated. In this process, the DEMATEL technique is taken into consideration. In the second part of the model, the aim is to determine the most appropriate investment strategies. To achieve this goal, a Rankin analysis is carried out using the TOPSIS technique. The main motivation

of this study is that there is no consensus in the literature on which are the most critical strategies required to eliminate the difficulties of nuclear energy projects. This situation creates difficulties for nuclear energy investors. The results obtained with the analysis to be carried out in this study are guiding both policy makers and investors. By implementing these strategies, it is possible to increase the effectiveness of nuclear energy investments in Turkey. The most important contribution of this study is the development of nuclear energy-based strategies required for Turkey to gain energy independence. On the other hand, it is possible to reduce the uncertainties in this decision-making process by developing a hybrid decision-making model. This allows for more realistic results to be achieved.

2. General Information about Nuclear Energy Investments

Energy investments refer to investments made for the purpose of developing infrastructure for energy production and distribution processes. These investments aim to ensure the economic development of the country and the security of energy supply. Owing to this situation, countries attach great importance to energy investments. Energy investments can be carried out in different types. The most well-known energy investments are fossil fuels. In this process, fossil fuels such as oil and natural gas are burned. In the meantime, electricity is obtained from the driving force of the smoke that emerges. One of the biggest advantages of fossil fuels is that their costs are lower than other types of energy. This increases the profitability of the projects. With the help of this issue, investors focus more on these projects. On the other hand, one of the most important disadvantages of these projects is that they cause carbon emissions. The combustion of fossil fuels such as coal and oil releases significant amounts of carbon gas into the atmosphere. This situation causes significant air pollution. If the necessary precautions are not taken, this situation can significantly threaten people's health.

Renewable energy projects are another type of energy investment. In this process, electricity is obtained using natural resources such as wind and sun. It is possible to talk about some advantages of this type of energy. First, countries can produce their own energy with renewable energy investments. This allows countries to achieve energy independence. In other words, countries that produce their own energy will not have to import energy from other countries. This situation also positively affects the current account balance of countries. Another advantage of renewable energy projects is that they are clean energy. Carbon emissions do not occur during the energy production process. This situation significantly reduces environmental pollution. In short, the most effective way to reduce the carbon emission problem is to develop renewable energy projects. This situation reduces the negative effects of the energy production process on human health.

Renewable energy projects also have some disadvantages. The initial cost of these projects is very high compared to fossil fuels. This situation makes investors very nervous. Similarly, it is very difficult to access the funds required for the realization of these investments. This situation also constitutes a very important obstacle for the development of renewable energy projects. Renewable energy projects are also very complex. This situation is another disadvantage of the projects. Advanced technologies must be used to realize complex projects. Similarly, qualified personnel are also needed in this process. Employing qualified personnel causes a significant increase in the operational costs of businesses. This situation creates a very important weakness for projects that already have very high initial investment costs.

Nuclear energy investments are another type of energy investment. Nuclear energy can produce more energy with less fuel compared to fossil fuels. In addition to this issue, nuclear power plants do not emit greenhouse gases in energy production. This situation has a very important role in combating climate change. Unlike renewable energy sources, it is possible to produce uninterrupted energy in nuclear power plants. Renewable energy projects are significantly affected by climatic differences. For example, there may be interruptions in the energy obtained from solar panels in the winter season. In contrast, there are no energy interruptions in nuclear reactors. This situation creates the opportunity to provide continuous energy to industrial production companies.

There are also some disadvantages in nuclear reactors. First, some waste is generated in nuclear energy production. Since this waste has radioactive properties, it threatens people's health. Therefore, this waste must be effectively disposed of. In addition to this condition, there is a risk of explosion in nuclear power plants. This situation poses a risk to people in the region. Many people lost their lives as a result of the explosion in the nuclear power plant in Chernobyl. This situation significantly worries the people living in the region. Because of this issue, some people in the countries are protesting against the installation of nuclear power plants.

3. Methodology

This study aims to determine the necessary effective strategies to effectively overcome the difficulties in nuclear energy projects. To achieve this goal, a two-stage decision-making model is developed.

3.1 DEMATEL

In the first stage of the study, the DEMATEL technique is taken into consideration in determining the importance weights of the selected criteria. This technique is a decision-making method used to analyze cause-effect relationships between criteria or elements in complex systems [15-17]. The details of the stages of this technique are given below.

Step 1 - Determining the Criteria: In this context, the criteria or factors in the system to be analyzed are defined. Criteria are usually determined by literature analysis [18].

Step 2 - Creating the Relationship Matrix: A direct relationship matrix is created using the relationships between the criteria and the impact levels with the evaluations of experts. The effects of the criteria on each other can be understood thanks to this matrix.

Step 3 - Normalization of the Matrix: The values in the direct relationship matrix are normalized. The main purpose in this process is to make the data analyzable.

Step 4 - Calculating the Total Relationship Matrix: The normalized matrix is used to see the total effect.

Step 5 - Calculating the Impact and Reaction Values: The total effect of a criterion on other criteria and how much a criterion is affected by other criteria can be understood.

Step 6 - Creating the Cause-Effect Diagram: The total interaction level of the criterion and whether the criterion is a cause, or a result are determined [19,20].

Step 7 - Decision Making: Which criteria are more critical, and which criteria should be given priority are determined [21].

3.2 TOPSIS

In the second phase of the study, strategy suggestions for overcoming the difficulties of nuclear energy projects are listed. To achieve this goal, TOPSIS technique is taken into consideration. TOPSIS is one of the multi-criteria decision-making methods [22]. This technique assumes that the best alternative is the one closest to the positive ideal solution and the farthest from the negative ideal solution when solving a decision problem [23-25]. The stages of the TOPSIS technique are given below.

Step 1 - Creating a Decision Matrix: The decision matrix contains the values of each alternative for each criterion.

Step 2 - Normalization of the Decision Matrix: If each criterion is on a different scale, the values are normalized.

Step 3 - Calculating the Weighted Normalization Matrix: The criteria in the decision matrix are weighted according to different importance levels.

Step 4 - Determining Positive and Negative Ideal Solutions: Benefit and cost criteria are considered separately.

Step 5 - Calculating Positive and Negative Distances: The distance of the alternatives to the ideal solutions is determined.

Step 6 - Calculating Similarity Values: The similarity coefficient to the ideal solution is calculated for each alternative.

Step 7 - Ranking the Alternatives: The alternative with the highest similarity coefficient value is the best option [26].

4. Results

There are two different stages of the proposed model. The analysis results of these two different stages are given below.

4.1 Weighting the Criteria

In this process, DEMATEL technique is taken into consideration in determining the importance weights of the selected criteria. The analysis results of the criteria weighting process are demonstrated in Table 1.

Table 1
Criteria Weighting Results

Criteria	Weighting Results
Financial Issue	**2**
Customer Expectations	**3**
Organizational Effectiveness	**4**
Technological Improvements	**1**

Table 1 gives information that technological improvement is the most critical indicator to overcome the problems of nuclear energy investments. Financial issues and customer expectations are other essential items in this regard. However, organizational effectiveness has the lower weight in comparison with the other determinants.

4.2 Ranking the Strategies

In the second stage, the strategies to overcome the problems in nuclear energy investments are ranked. To achieve this objective, TOPSIS technique is taken into consideration. Ranking results of these alternatives are denoted in Table 2.

Table 2
Strategy Ranking Results

Strategies	Ranking Results
Overcoming Financing and Economic Challenges	**2**
Reducing Safety and Environmental Concerns	**4**
Improving Regulation and Policies	**3**
Developing Qualified Human Resources	**5**
Increasing Social Acceptance	**6**
Technological and Operational Developments	**1**

Table 2 underlines that technological and operational development is the most critical strategy to minimize the negative impacts of nuclear energy investments. Overcoming financing and economic challenges and improving regulation and policies are other critical issues in this situation. Reducing staff and environmental concerns, developing qualified human resources, and increasing social acceptance are last on the list.

5. Conclusion

This study aims to identify the most appropriate strategies for the development of Turkey's nuclear energy investments. Within this framework, a two-stage decision-making model is established. In the first part of the study, the importance weights of the selected criteria are calculated. In this process, the DEMATEL technique is taken into consideration. In the second part of the model, the aim is to determine the most appropriate investment strategy. Moreover, a ranking analysis is carried out using the TOPSIS technique to achieve this goal. It is concluded that technological improvement is the most critical indicator of overcoming the problems of nuclear energy investments. Financial issues and customer expectations are other essential items in this regard. However, organizational effectiveness has a lower weight than the other determinants. On the other hand, it has been identified that technological and operational development is the most critical strategy for minimizing the negative impacts of nuclear energy investments. Similarly, overcoming financing and economic challenges and improving regulations and policies are other critical issues.

Some policy recommendations can be made to increase nuclear energy capacity. First, investment incentive policies significantly support the development of these projects. Tax reductions and subsidies can be provided for nuclear energy investments. This situation allows the cost effectiveness of the projects to be increased. As a result of this situation, it is possible to increase the profitability of the projects. Similarly, long-term purchase guarantees can be offered to investors. This situation supports the increase of the income of investors for a certain period. This application also allows investors to focus on these projects. Establishing international partnerships also contributes significantly to achieving this goal. In this context, international cooperation can be increased to develop nuclear energy technologies and build reactors. Owing to this condition, it is possible to provide technology transfer. On the other hand, low-interest loans and public-private partnership models can be applied for private sector investments.

Ensuring technological development is another policy suggestion that can be taken into consideration for the development of nuclear energy projects. In this context, research and development studies can be carried out to increase nuclear fusion studies. This situation allows for the development of new technologies for nuclear energy production. Therefore, countries should invest in new technologies such as fusion energy in the long term. Furthermore, nuclear energy innovations should be encouraged through cooperation between universities, research centers and the private sector. This situation allows for the significant development of nuclear energy technology.

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