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Araştırma Makalesi ● Research Article

Selection of the Best LNG Natural Gas Supplier with Multi-Criteria Decision-Making Techniques: Turkey Example in Current Conditions[i]

Çok Kriterli Karar Verme Teknikleri ile En İyi LNG Doğal Gaz Tedarikçisinin Seçimi: Mevcut Koşullarda Türkiye Örneği

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ÖZ

Tedarikçi seçimindeki karar, bir firmanın başarılı olması için çok büyük bir öneme sahiptir. Sıvılaştırılmış Doğal Gaz (LNG), günümüz şartlarında, özellikle doğal gaz arz güvenliği durumunda, doğal gaz arz güvenliğini sağlamak için çok önemli bir alternatiftir. LNG tedarikçi seçimi bu sürecin en önemli anahtar noktasını oluşturmaktadır. Bu çalışma, mevcut koşullara göre İdeal Çözüm (TOPSIS) Yöntemlerine Benzerlikle Analitik Hiyerarşi Süreci (AHP) ve Sipariş Tercihi Tekniği kullanılarak Türkiye için en iyi LNG doğal gaz tedarikçisinin seçimini yapmayı amaçlamaktadır. Bu amaçla ana ve alt kriterleri belirlemek üzere uzman görüşleri, faaliyet raporları ve literatür taraması yapılmıştır. Uzman Seçim Yazılımı kullanılarak AHP yöntemi uygulanır ve en iyi tedarikçi seçimi için TOPSIS Microsoft Excel ile analiz edilmiştir. Ayrıca, hangi kriterlerin hangi alternatifleri öne çıkardığı, sonuçta hangi kriterlerin belirleyici, hangilerinin belirleyici olmadığı gösterilmiştir.

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A B S T R A C T

Decision of supplier selection has a crucial importance for a firm to succeed. Liquefied Natural Gas (LNG) is a crucial alternative to ensure the safety of natural gas supply in today's conditions, especially for the state of natural gas supply security. LNG supplier selection constitutes the most important key point of this process. This study aims to make the selection of the best LNG natural gas supplier for Turkey using the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods according to the current conditions. For this purpose, expert opinions, activity reports and literature reviews were made to determine main and sub criteria. AHP method is applied by using Expert Choice Software and TOPSIS was analyzed with Microsoft Excel for the best supplier choice. In addition, it has been shown that which criteria brings which alternatives forward, which criteria are decisive in the result and which are not decisive.

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INTRODUCTION

Decision making is defined as the process of selecting one or more of the alternatives that are best suited to the objectives or objectives from all existing alternatives. Decision theory is defined as an analytical and systematic approach to decision-making. Multi-criteria decision making (MCDM) is an important place among decision-making techniques and is an area that adds value to operations research. MCDM is based on determining the best alternative or option in cases where there are multiple criteria or objectives. Figure 1 shows the steps for decision theory. Decision making techniques are used in a wide range of areas. One of the areas where decision making techniques are applied is the field of energy supply. The single criteria decision-making technique is used to select the most cost-effective option in energy supply. However, especially in the last 30-40 years, many criteria for energy supply are widely used in decision making techniques (Samouilidis and Mitropoulos, 1982).

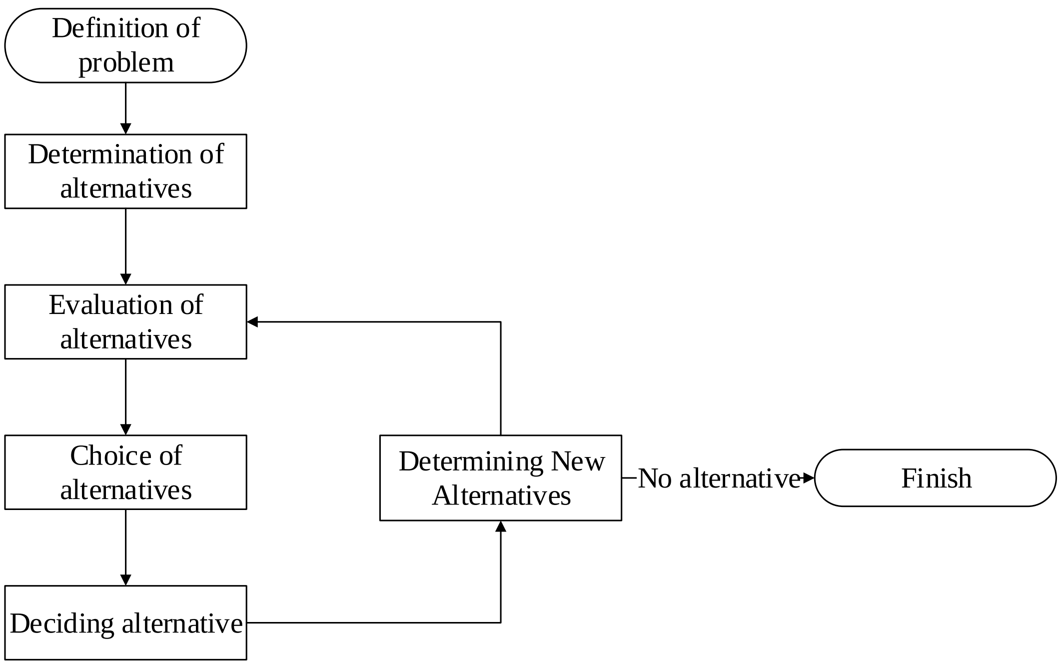


Figure 1. The steps in decision theory

Energy supply security is basically based on the principle of the diversity of energy supply and reaching energy resources in an economic way (Erdal and Karakaya, 2012). Even the smallest supply cuts to be experienced in natural gas-dependent countries such as Turkey can lead to crises in economic and social foundations. Especially in previous years, it has been experienced that only a few specific supplier countries and natural gas agreements made through pipelines have caused many crises in Turkey to create energy supply security. For this reason, besides the transmission made by pipelines, the increase in LNG transmission has significantly reduced the dependence on natural gas pipelines. Thus, both source diversity and supplier diversity are provided. However, this process has resulted in the selection of the appropriate LNG supplier for Turkey and the process in which the criteria should be used. This study was made on the selection of the appropriate LNG supplier with MCDM techniques in the current conditions.

The application area of AHP and TOPSIS methods is very wide and they are one of the well-known two techniques of

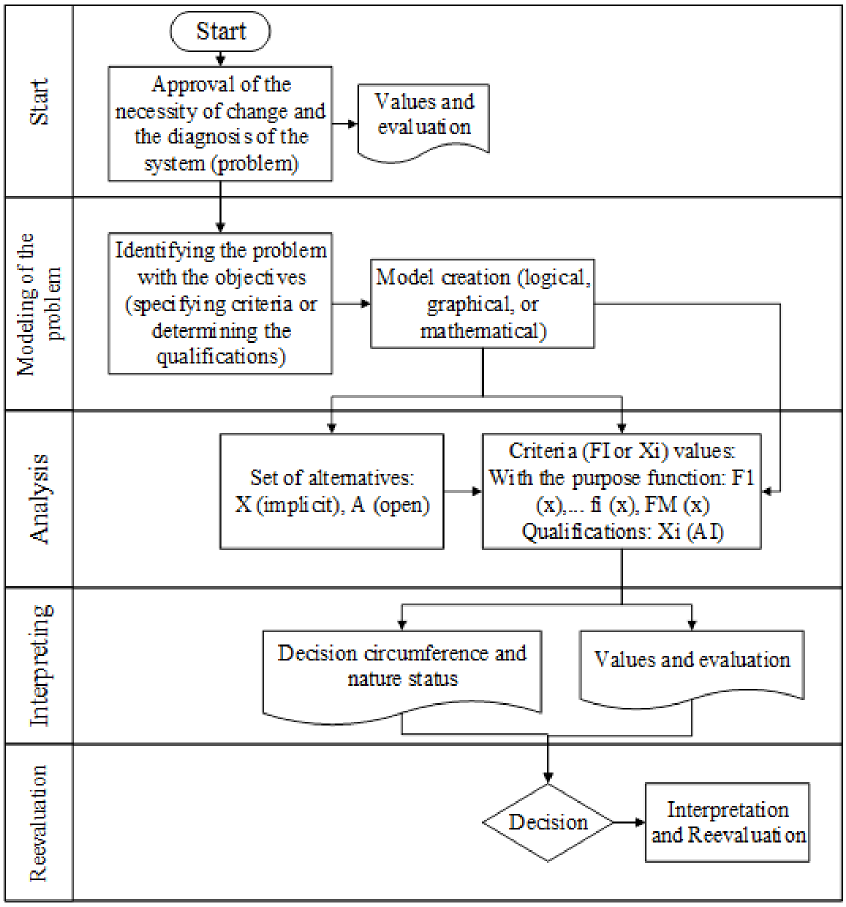
MCDM. Information on these methods is provided in Section 2. Literature surveys, where many criteria decision making methods are applied, can be seen as many areas where these methods are applied (Govindan et al., 2015; Ho et al., 2010; Liberatore and Nydick, 2008; Srivastava, 2007). The best selection problems are addressed in the TOPSIS application areas such as selecting airline company for travel (Liao, 2013; Torlak et al., 2011; Tsaur et al., 2002), facility location (Ertuğrul and Karakaşoğlu, 2008), weapon selection (Dağdeviren et al., 2009), best project selection (Mahmoodzadeh et al., 2007), best warehouse location selection (Ashrafzadeh et al., 2012), best tourism destination(Önder et al., 2013) supplier selection (Ellram, 1990; Wang et al., 2009) etc. Researchers tried to solve problems using AHP in various areas such as vendor selection (Bayazit and Karpak, 2005; Tam and Tummala, 2001), project management and selection (Al-Harbi, 2001; Huang et al., 2008), supplier selection (Shaw et al., 2012), ERP selection (Wei et al., 2005), software selection (Lai et al., 2002).

In the first part of the study, decision-making and decision theory, as well as MCDM techniques, general literature screening has been given. The second part of the study revealed the criteria and alternatives necessary for the selection of the most suitable LNG (liquefied natural gas) supplier for Turkey with the techniques of MCDM. First, the aim of the work is to explain why the gas supply security is vital, explaining why the choice of LNG suppliers is necessary. In the last chapter, the Expert Choice program has performed phases such as AHP method, determining objectives, determining alternatives, determining the main and sub criteria, creating binary comparison matrices related to the main and lower criteria, and LNG supplier selection is provided. Then, by taking advantage of the weights obtained from the Expert choice outputs, the appropriate LNG supplier selection was made with the TOPSIS method in Excel program. In the final section, the results of the study were evaluated.

MCDM Process

MCDM describes the holistic structure of the problem solving in Figure 2, consisting of five phases (Chankong and Haimes, 1983).

Figure 2. MCDM Process



In the initial phase, the process begins as soon as it detects the need to change the flow of the system (problem) it is interested in. The condition is diagnosed, and the expression of ultimate purpose is revealed. There are different tasks/jobs to be made during the formulation of the problem. These are;

- Creation of a set of sub-objectives (criteria), expressed in an abstract manner in the form of more functional and specific objectives of the upper objective,
- The necessary elements of the system, the boundaries of the problem and the environmental conditions of the system is clearly revealed.

In the modeling phase, when the system's perimeter and set of purposes are defined, appropriate models can be created for the problem. "Model" is a structure that consists of a combination of key variables and their logical (or physical) relationships that will provide a comprehensive analysis of the relevant aspects of the system in an effective and meaningful manner. There are several forms of models which are; simple logical models, graphic models, complex physical models, mathematical models. If alternatives are not data at the initial stage, they can perform the function of producing alternative styles suitable for the problem.

In the problems of MCDM, the alternatives should be compared and the qualifications (a set of measurements for the objectives/criteria) must be clearly identified and revealed. This set of measurements can take different names such as "performance metrics/Criteria/index" or "objective (benchmark) function". For an alternative, the measurement levels of the qualifications are determined on a suitable scale. While these scales function as a comparison or measurement standard, the specified measurement levels are assigned as the degree of reaching the objectives that have been expressed in the previous stage. For an alternative, the measured values of the relevant qualifications are either subtracted from the model (unpredictable) or directly determined through the evaluation of subjective judgments.

During the analysis and evaluation phase, each alternative is evaluated based on a decision rule or set of rules that are predefined and used to rate alternatives. The alternative that takes the highest rank according to the decision rule is selected for interpretation. If the process is an open circular process, the process steps end at this point. If the resulting outcome does not satisfy the decision maker, in other words, if it is insufficient, the problem is returned to the formulation phase (the second step) using the information obtained for the observed output. A process in this structure is defined as a closed circular process.

AHP

The AHP method was developed by Thomas L. Saaty in the 1970s and is one of the MCDM approaches based on bilateral comparisons (Saaty, 2008). In AHP, it is a method that attracts the attention of many researchers because of the easy use of the data needed to model and solve the decision problem. AHP is a decision support tool that can be used to solve complex multi-criteria decision problems. In addition to the concrete and quantitative criteria based on the judgments of experts, abstract and qualitative criteria are also an approach that can include the problem. This method allows both objective and subjective factors to be taken into consideration when choosing the best alternative. Nowadays, most people decide by using self-assessment-based judgments or using mathematical models that cannot be proved or have inadequate results. In this case, it is a decision methodology that is needed, simplifying the complex problem, making it easier to understand and demonstrating the relationship between the components that make up the problem. Such a methodology is also included in AHP (Soyuer and Kocamaz, 2003).

TOPSIS

TOPSIS was developed by Yoon and Hwang as an alternative to ELECTRE method in 1980 and is considered one of the most common in accepted variations (Hwang et al., 1993). It was proposed by Hwang and Yoon in 1981 to determine the best alternative based on the understanding of the negotiated solution. The compromise solution can be expressed as the closest to the positive ideal solution (optimum resolution) and the most remote solution to the negative ideal solution (Tzeng and Huang, 2011). Basic concept of method; The chosen alternative, in a kind of geometric sense, should be at the shortest distance from the ideal solution and the most distant distance from the negative-ideal. The TOPSIS method assumes that each criterion has a monotony tendency to increase or diminishing benefits. Hence, ideal and negative-ideal solutions are easy to identify. The Euclid distance approach aims to assess the relative proximity of alternatives to the ideal solution. Thus, the order of choice of alternatives can be taken through a series of comparisons of these relative distances (Herişçakar, 1999). It was later implemented by this idea (Zeleny, 1982) and developed by (Hwang and Yoon, 1981) and (Hwang et al., 1993). The TOPSIS consist of 6 stages.

Which are;

- Establishing a normalized decision matrix
- Forming a weighted normalized decision matrix

- Determination of Ideal and negative ideal solutions
- Calculation of separation measurement
- Calculating relative proximity to ideal solution
- Arrangement of preference order

The TOPSIS method was developed based on ELECTRE. Therefore, it is not surprising that the first two phases of the methods are the same. It begins with the basis of a normalized decision matrix to compare both ELECTRE and TOPSIS scales. In the second phase, both methods take the weight values of the choices from decision makers. In the third stage, methods differ. As a difference, when performing the qualifiers according to the superiority of one of the ELECTRE alternatives, TOPSIS shows that the alternative which is closest alternative to the ideal solution and best alternatives to the negative ideal solution is the ideal solution (Kaya and Kahraman, 2004). One advantage of TOPSIS is that each alternative has its own value. TOPSIS method is used to solve MCDM problems in many areas such as, supply chain management, logistics, design, engineering, manufacturing, business and marketing management, health, safety, environmental management, human resources management, energy management, chemical engineering and resource management.

Turkey's energy supply assessment with MCDM

The security of supply in the energy sector is an international issue that concerns many countries, since it determines the relations between exports of energy resources and imported countries. In this context, energy supply security plays an important role in determining world policies. As a requirement of global energy policies and balances, under ordinary circumstances, no country is fully independent of natural gas supply and demand security issues. In other words, both the energy source and those who demand the energy source are unable to move on their own.

In cases where supply security is compromised, bureaucratic sanctions, embargos and even hot clashes can be seen. Even the smallest supply cuts to be experienced in natural gas-dependent countries such as Turkey can lead to crises in economic and social foundations. In addition, irregular and unstable natural gas supply can affect the efficiency of the country's industrial production (Satman, 2007).

AHP Application

The main criteria that should affect the decision in this application are listed below.

- Cost
  - Price of gas (unit price as energy)
- Current political situations
  - Trade agreements with the supplier country
  - Supplier country's political stability
  - Political relations with the supplier country
  - The supplier country's LNG policy with foreign countries
- Quality
  - Product quality (such as upper heat, density, gas cleaning)
  - Technical capacity (Unloading time, Heat earned on the road, ship quality)
  - Loading terminal quality, (loading speed, product supply time)
  - Compliance with procedures (HSE, QAQC)
  - Reputation and position in the sector
  - Market share
- Logistics
  - Distance length
  - Seasonal conditions (the presence of the southern and North hemisphere)
  - Risk factor (road and safety status)
  - Tax and transportation expenses (road expenses)

After the sub-criteria have been defined, several alternative options will be given to decide on the selection. The alternatives identified in the study are suppliers; The United States of America (USA), Algeria, Qatar and Nigeria are four.

Establishment of AHP

The most important phase of AHP is the creation of a hierarchical structure. At this stage, a hierarchical structure of the main criteria which are determined at second stage and sub-criteria determined for each criterion was established starting from the objective in the first stage. The structure of the AHP process is shown in Figure 3. With the help of the Expert Choice program, this structure was created by marking the target identification, key criteria and sub-criteria respectively.

Figure 3. Hierarchical structure of criteria

At this stage, similar elements at each level of the hierarchy are compared with the next level of criteria. The binary comparison matrix of all elements is created. In this matrix, 1 values are placed in the diagonal of the matrix because the comparison of an element with the number 1 is expressed. N(n-1)/2 compares has been done for n-element matrix has been compared. The priority values for comparisons in this work are:

- Annual reports belonging to Energy Market Regulatory Board (EPDK), Ministry of Energy and Petroleum Pipeline Corporation(BOTAS) of previous years,
- Short and long-term planning reports based on comparison and energy projections of past and future years,
- Mutual agreements and related studies, which are expected in recent or previous and upcoming decades with the supplier countries,
- Financial and political reports on import and export of energy,
- Current LNG and natural gas related journals, studies, projects and academic studies

Taken into consideration. The priority values are shown in Figure 4 because of the pairwise comparisons of the main criteria with Expert Choice and the resulting account. Because of the bilateral comparison of the main criteria, "current political situations" and "quality assessments" with a relative value of 0.333 were determined as the main criteria. The cost and logistics values of the energy unit price are determined as benchmarks of less weight. The Expert Choice program automatically calculates the consistency rate. The consistency ratio has been obtained as 0.00, resulting in a consistent comparison because the acceptable limit 0.10.

	COST	CURRENT	QUALITY	LOGISTICS
COST		2,0	2,0	1,0
CURRENT POLITICAL SITUATION			1,0	2,0
QUALITY				2,0
LOGISTICS	Incon: 0,00			

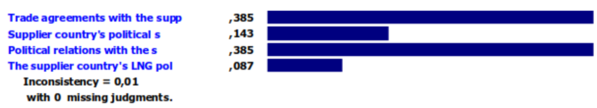
Figure 4. Comparisons, importance level, and consistency ratios of the main criteria

Based on the comparison of the sub-criteria under the main criterion of "current political situations", "trade agreements with the supplier country" 0.385 points, "supplier country's political stability" 0.143 points; "Political relations with the Supplier Country" are calculated as 0.385 points and shown in Figure 5-A. "The supplier country's LNG policy with foreign countries" has generated a severity rating of 0.087 points with the Expert Choice program. The consistency rate has been obtained as 0.01 and the comparison is consistent because it is lower than the acceptance limit which is 0.10.

"Quality" according to the main criteria "technical capacity (unloading time, heat earned on the road, ship Quality)" 0.081 points; "Load terminal quality, (loading speed, product supply time)" 0.050 points; "Compliance with procedures (HSE, QA-QC) 0.206 points are calculated as 0.431 points of product quality (top heat, density, gas cleaning) and shown in Figure 5-B. "Reputation and position in the sector" 0.087 points, "market share" 0.144 points by taking the output of the Expert Choice program has created the severity ratings. The consistency rate has been obtained as 0.01 and the comparison is consistent because it is lower than the acceptance limit.

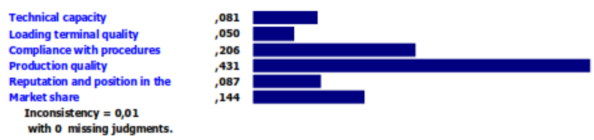
Looking at the main criterion of "logistics", "distance Length" 0.125 points, "seasonal conditions (the state of the South and North hemisphere)" 0.078 points, "risk factor (road and safety status)" is calculated as 0.492 points and shown in Figure 5-C. "Tax and handling expenses (road expenses)" 0.306 points, taking the output of severity ratings with the Expert Choice program. The consistency rate has been obtained as 0.02 and the comparison is consistent because it is lower than 0.10.

	Trade agreen	Supplier	Political	The supp
Trade agreements with the supplier country		3,0	1,0	4,0
Supplier country's political stability			3,0	2,0
Political relations with the supplier country				4,0
The supplier country's LNG policy with foreigı	Incon: 0,01			



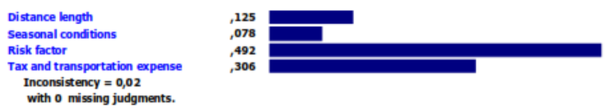
a

	Technical ca	Loading	Complia	Producti	Reputati	Market s
Technical capacity		2,0	3,0	5,0	1,0	2,0
Loading terminal quality			4,0	6,0	2,0	3,0
Compliance with procedures				3,0	2,0	2,0
Production quality					5,0	3,0
Reputation and position in the						2,0
Market share	Incon: 0,01					



b

	Distance le	Seasona	Risk fact	Tax and
Distance length		2,0	4,0	3,0
Seasonal conditions			5,0	4,0
Risk factor				2,0
Tax and transportation expenses	Incon: 0,02			

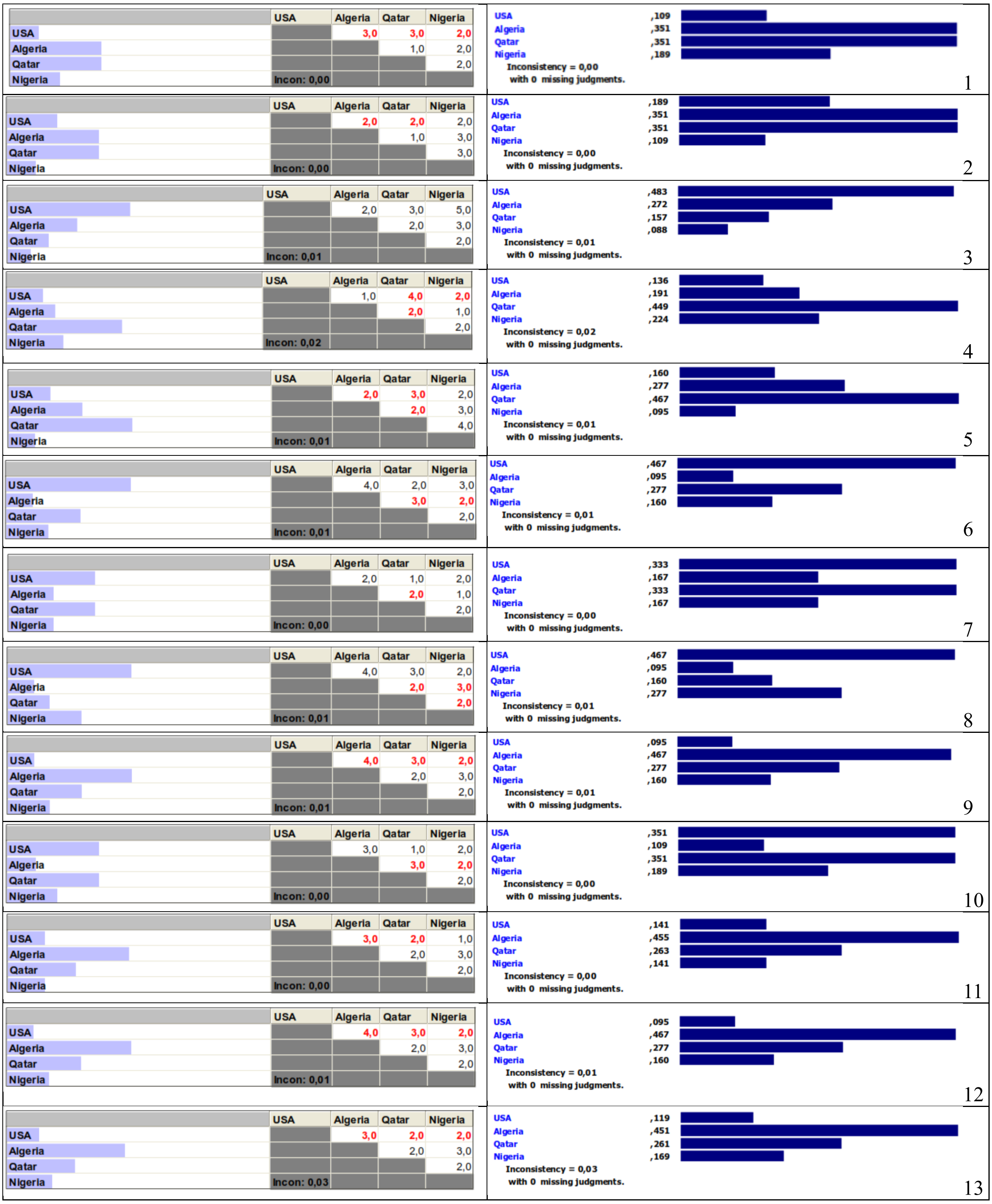


c

Figure 5. comparisons with the sub-criteria of the main criteria, severity ratings and consistency ratios (a-current political situation, B-quality, C-Logistics)

In the next stage, binary comparisons of options were made according to each of the sub-criteria at the second level of the hierarchy, and the priority values of each were found with the help of the Expert Choice package program. Figure 6 provides Expert Choice printouts for comparison of sub-criteria between supplier countries, severity ratings and consistency ratios. The severity rating and consistency ratio were calculated as 0.00 and the comparison was determined to be consistent because it is lower than the acceptance limit.

These sub-criteria are; 1-"Cost over energy unit price" 2-"commercial agreements made with supplier countries" 3-"supplier country's political stability" 4-"supplier country with political relations" 5-"supplier of the country's LNG policy with foreign countries" 6-"technical capacity" 7 -"Installation terminal quality" 8-"compliance with procedures" 9-"product quality" 10-"reputation and position in the sector" 11-"market share" 12-"distance Length" 13-"seasonal conditions" 14-"Risk factor" 15-"tax and handling expenses" are determined.



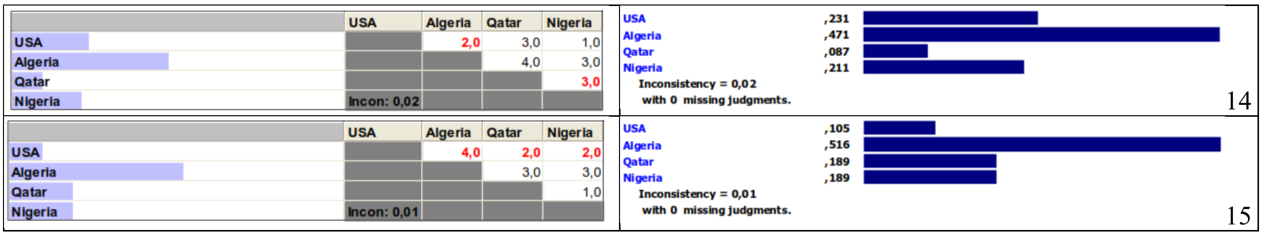


Figure 6. Comparison of 1-15 criteria between supplier countries, severity rating and consistency ratio

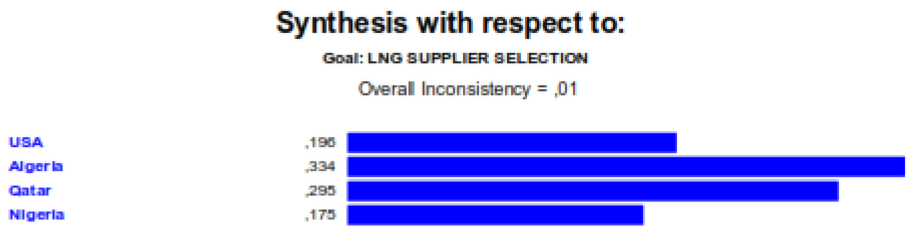


Figure 7. Suitable LNG supplier Selection

In the comparison of LNG suppliers in Figure 7, Algeria 0.334 was found to be the highest weight of LNG supplier. Algeria is followed by the Qatar with a weighted score of 0.295 and United States with 0.195 weighted points. Nigeria remained in the last row with a score of 0.175 The consistency rate has been obtained as 0.01 and the comparison is consistent because the acceptance limit is 0.10. Consequently, the most suitable LNG supplier in current conditions is determined as Algeria because of the analytical hierarchy process with the Expert choice application.

Figure 8 provides a performance sensitivity graph for each supplier. The suppliers of Algeria and Qatar are around 70% in cost, while the Nigeria supplier is a little over 35%. The United States is in the last row with 20%. In current political situations, the US, Algeria and Qatar suppliers are around 70%, while the Nigeria supplier is a little over 25%. In quality, the United States, Algeria and Qatar are around 60%, while the Nigeria supplier is slightly above 35%. In the logistics criteria, Algeria is in the top position with 90%. Algeria, USA, Nigeria and Qatar suppliers are following the values of 35%. When the value of any criterion is changed, the changes, which automatically consist of other criteria and alternatives, are seen simultaneously. After all the above procedures, the final stage of the hierarchy was passed to the determination of the appropriate alternative.

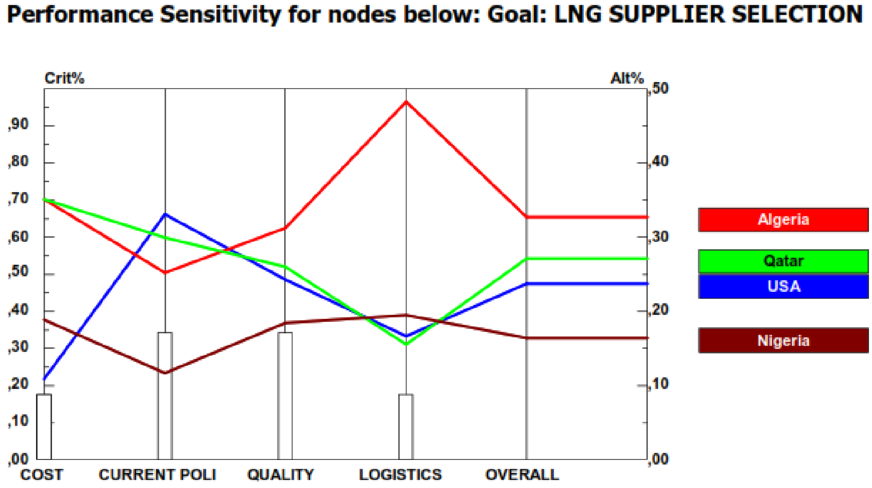


Figure 8. Performance sensitivity (in percent)

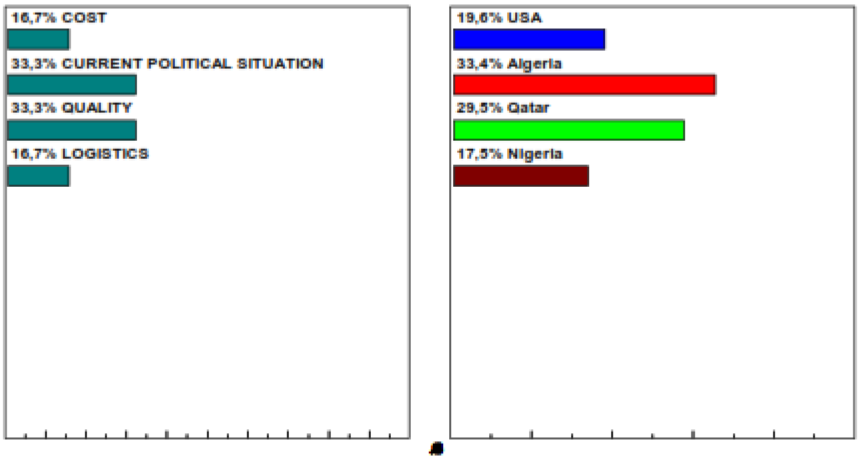


Figure 9. Dynamic sensitivity

In Figure 9, dynamic sensitivity is given. Accordingly, the main criteria "cost"% 16.7, "current political situations" 33.3%, "quality" 33.3%, "logistics" is seen as 16.7%. Algeria is a supplier of 33.4%, with a percentage of 29.5% in Qatar and Qatar followed by the United States with a percentage of 19.6%. Nigeria remained in the last row with a percentage of 17.5%.

In Figure 10, the priority values of the decision elements in the entire hierarchy are shown in detail.

Table 1. Priority values by suppliers

Alternatives		Level 1	Level 2	Priority
Algeria	COST (L: 0,167)		PRICE OF GAS (L: 1,000)	,058
	CURRENT POLITICA...		Trade agreements with the supplier country (L: 0,385)	,045
			Supplier country's political stability (L: 0,143)	,013
			Political relations with the supplier country (L: 0,385)	,018
			The supplier country's LNG policy with foreign countries (L: 0,087)	,008
	LOGISTICS (L: 0,167)		Distance length (L: 0,125)	,010
			Seasonal conditions (L: 0,078)	,006
			Risk factor (L: 0,492)	,039
			Tax and transportation expenses (L: 0,306)	,026
	QUALITY (L: 0,333)		Technical capacity (L: 0,081)	,003
			Loading terminal quality (L: 0,050)	,003
			Compliance with procedures (L: 0,206)	,007
			Production quality (L: 0,431)	,067
			Reputation and position in the sector (L: 0,087)	,003
			Market share (L: 0,144)	,022
USA	COST (L: 0,167)		PRICE OF GAS (L: 1,000)	,018
	CURRENT POLITICA...		Trade agreements with the supplier country (L: 0,385)	,024
			Supplier country's political stability (L: 0,143)	,023
			Political relations with the supplier country (L: 0,385)	,058
	CURRENT POLITICA...		The supplier country's LNG policy with foreign countries (L: 0,087)	,005
	LOGISTICS (L: 0,167)		Distance length (L: 0,125)	,002
			Seasonal conditions (L: 0,078)	,002
			Risk factor (L: 0,492)	,019
			Tax and transportation expenses (L: 0,306)	,005
	QUALITY (L: 0,333)		Technical capacity (L: 0,081)	,013
			Loading terminal quality (L: 0,050)	,006
			Compliance with procedures (L: 0,206)	,032
			Production quality (L: 0,431)	,014
			Reputation and position in the sector (L: 0,087)	,010
			Market share (L: 0,144)	,007
Qatar	COST (L: 0,167)		PRICE OF GAS (L: 1,000)	,058
	CURRENT POLITICA...		Trade agreements with the supplier country (L: 0,385)	,045
			Supplier country's political stability (L: 0,143)	,007
			Political relations with the supplier country (L: 0,385)	,034
			The supplier country's LNG policy with foreign countries (L: 0,087)	,014
	LOGISTICS (L: 0,167)		Distance length (L: 0,125)	,006
			Seasonal conditions (L: 0,078)	,003
			Risk factor (L: 0,492)	,007

		Tax and transportation expenses (L: 0,306)	,010
	QUALITY (L: 0,333)	Technical capacity (L: 0,081)	,008
		Loading terminal quality (L: 0,050)	,006
		Compliance with procedures (L: 0,206)	,011
		Production quality (L: 0,431)	,040
		Reputation and position in the sector (L: 0,087)	,010
		Market share (L: 0,144)	,013
Nigeria	COST (L: 0,167)	PRICE OF GAS (L: 1,000)	,032
	CURRENT POLITICA...	Trade agreements with the supplier country (L: 0,385)	,014
		Supplier country's political stability (L: 0,143)	,004
		Political relations with the supplier country (L: 0,385)	,018
		The supplier country's LNG policy with foreign countries (L: 0,087)	,003
	LOGISTICS (L: 0,167)	Distance length (L: 0,125)	,003
		Seasonal conditions (L: 0,078)	,002
		Risk factor (L: 0,492)	,017
		Tax and transportation expenses (L: 0,306)	,010
	QUALITY (L: 0,333)	Technical capacity (L: 0,081)	,004
		Loading terminal quality (L: 0,050)	,003
		Compliance with procedures (L: 0,206)	,019
		Production quality (L: 0,431)	,023
		Reputation and position in the sector (L: 0,087)	,005
		Market share (L: 0,144)	,007

Selection of suitable LNG supplier with TOPSIS method

TOPSIS application includes a solution process consisting of 6 steps. The phase of this solution process is as follows. The weights and matrix values obtained in the TOPSIS application were created by benefit from AHP outputs.

Creation of the decision Matrix (A)

The decision matrix lines include the decision alternatives that are required to sort the superiority, and the evaluation criteria to be used in deciding on the columns. Alternatives in this study; It is determined to be USA, Algeria, Qatar and Nigeria.

Criteria's

- CR1: Trade agreements with the supplier country
- CR2: Supplier country's political stability
- CR3: Political relations with the supplier country
- CR4: The supplier country's LNG policy with foreign countries
- CR5: Product quality (such as upper heat, density, gas cleaning)
- CR6: Technical Capacity (Unloading time, Heat earned on the road, ship quality)
- CR7: Loading terminal quality, (loading speed, product supply time)
- CR8: Compliance with procedures (HSE, QA-QC)
- CR9: Reputation and position in the sector
- CR10: Market share
- CR11: Distance length
- CR12: Seasonal conditions
- CR13: Risk factor
- CR14: Tax and transportation costs
- CR15: Cost (energy unit price)

In this case, the created (A) matrix structure is given in Table 1.

Table 2. Creating a TOPSIS decision matrix

	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10	CR11	CR12	CR13	CR14	CR15
US	29	20	34	4	11	7	29	12	12	6	2	1	17	4	22
Algeria	45	13	18	8	3	3	7	67	3	22	10	4	39	26	58
Qatar	45	7	54	14	8	6	11	40	10	13	6	6	7	10	58
Nigeria	14	4	18	3	4	3	19	23	5	7	3	2	17	10	32

Normalized decision Matrix (R) creation

The normalized decision matrix is calculated by taking advantage of the elements of matrix A and using equality 1.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad i = 1, 2, \ldots, m \quad j = 1, 2, \ldots, n \tag{1}$$

Establishing a weighted decision matrix (V)

The columns of the normalized decision matrix are multiplied by the WJ weight values given to the criteria. Weights were formed by benefits from AHP outputs. According to the importance given to the criteria;

$$V_{ij} = W_i R_{ij} \quad J = 1, 2, \ldots, J \quad i = 1, 2, \ldots, n.$$

Each value of the generated R matrix is then multiplied by the corresponding W_{ij} value and the V_{ij} matrix shown in Table 3 is created;

Table 3. Creating a TOPSIS V matrix

		Criteria														
		CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10	CR11	CR12	CR13	CR14	CR15
	Weights	0,13	0,05	0,13	0,03	0,03	0,02	0,07	0,14	0,03	0,05	0,02	0,01	0,08	0,01	0,17
Alternative	USA	0,41	0,79	0,49	0,24	0,76	0,69	0,78	0,15	0,72	0,22	0,79	0,13	0,37	0,13	0,75
	Algeria	0,63	0,52	0,26	0,47	0,21	0,30	0,19	0,81	0,18	0,81	0,16	0,53	0,84	0,87	0,29
	Qatar	0,63	0,28	0,79	0,83	0,55	0,59	0,30	0,49	0,60	0,48	0,26	0,79	0,15	0,33	0,29
	Nigeria	0,20	0,16	0,26	0,18	0,28	0,30	0,51	0,28	0,30	0,26	0,53	0,26	0,37	0,33	0,52

Creating ideal (A +) and negative ideal (a-) solutions

The TOPSIS method assumes that each evaluation factor has a monotonous ascending or descending tendency. The ideal solution is composed of the best performance values of the weighted normalized decision matrix, while the ideal negative solution consists of the worst values.

To create the ideal solution set, the weighted evaluation factors in the V matrix, i.e. the largest of the column values, are selected. The ideal set of solutions has been found as follows.

A * = {(0.08), (0.04), (0.1), (0.02), (0.02), (0.01), (0.05), (0.12), (0.02), (0.04), (0.02), (0.01), (0.01), (0.07), (0.01), (0.11)}.

The negative ideal solution set is created by selecting the weighted evaluation in the V matrix, which is the smallest of the column values. The negative ideal solution set has been found as follows.

A ' = {(0.03), (0.01), (0.03), (0.01), (0.01), (0.01), (0.01), (0.02), (0.01), (0.01), (0.01), (0.01), (0.01), (0.01), (0.04)}.

Calculation of separation criteria

The method of calculating Euclid distance is used to calculate the separation criteria. The distance of each alternative to the ideal solution is given in equality 2;

Calculating relative proximity to ideal solution

The calculation of the relative proximity of the decision points to the ideal solution (Ci *) is shown in equality

$$C_i^* = \frac{S_i'}{S_i' + S_i^*} \tag{4}$$

Table 4. Creating a TOPSIS C calculation

	Distance To Best	Distance To Worst	Score	Rank
US	157.692.958.230.514	15.088.120.442.600.900	0,488963	3
Algeria	15.074.984.163.727.200	15.413.782.647.997.700	0,505556	1
Qatar	1.431.204.357.736.300	1.403.220.661.058.840	0,495064	2
Nigeria	18.544.468.280.531.200	0.6620101535209268	0,263072	4

When creating Table 4, the criterion used for evaluation is the share of the negative separation measure in the total separation measure. Where the CI * value is $0 \leq ci * \leq 1$ and the ci * = 1 is located at the positive ideal solution point of the relevant alternative, the CI * = 0 indicates that the relevant alternative is at the negative ideal solution point.

According to the results, Algeria has received the highest value with a value of 0.5055. Qatar is the second highest value with 0.4950. The United States is the third with a value of 0.4889 and Nigeria is the last in the 0.2630.

Algeria >Qatar >USA > Nigeria

Thus, both the AHP and the TOPSIS method have reached the same conclusion.

Results

Several procedures have been made for the selection of the most suitable LNG supplier for Turkey with the MCDM techniques. First, the general natural gas market used in practice and the information contained in the literature examined the most popular criteria used by the researchers identified the appropriate criteria for the problem of supplier selection. They are presented as four main criteria and fifteen sub-criteria. After determining the supplier selection criteria, the network structure, which reveals the relationships between the main criteria and the sub-criteria, was created together with the working team. After the creation of the network structure, to make binary comparisons of related items on the network, commercial directors of natural gas in financial matters, long-range captains on road and logistics issues, quality issues such as Interviews and studies have been conducted with the quality experts. Our main criteria are; Energy unit price above cost, current political situations, quality and logistics are determined. In addition to the current requirements, the four most suitable LNG suppliers are presented in USA, Algeria, Qatar and Nigeria.

In the study, it is important that the decision makers used in the literature to be able to use their judgments by making bilateral comparisons and by controlling the consistency of these judgments and reducing the subjectivity, the AHP The TOPSIS method, which is a method based on the distance of differences between each other and more mathematical approaches, is used together. The AHP method is solved by the Expert Choice program because it can calculate by producing fast and consistent solutions, allowing sensitivity analysis and storing all data in a single database. The TOPSIS solution was made with the Excel program due to its flexible structure and very fast result retrieval features.

In our study, the method of TOPSIS MCDM was implemented with AHP. In addition, other methods such as Promethee or ELECTRE integrated with AHP can be used to select the best supplier and the results are comparable. In addition, criterion weights can be obtained using the analytical network process (ANP) method, which takes into consideration the interaction between criteria and options when it is encountered with factors such as the criteria affecting each other in supplier selection problems. Fuzzy theory, Fuzzy AHP methods can be incorporated into the decision-making process due to ambiguities in decision-making processes.

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