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A Multi-Objective Optimization Model for the Oil Supply Portfolio on Sea and Land

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Abstract

Background and Theoretical Basis: One of the most important concerns of most oil-exporting countries is determining the optimal oil Supply Portfolio (on Sea and Land) because the non-commitment of buyer countries can cause serious damage to the revenue sources of exporting countries due to their high need for oil exports.

Methodology: The supply risks are first identified based on the opinion of experts, all of whom are experts in the National Iranian Oil Company, especially in the contracts department, and then weighted using the analytic hierarchy process (AHP) technique.

Findings: The major countries importing oil from Iran are then ranked based on weight. Next, the result of this rating is entered into the mathematical programming model. The results of solving the model indicate the optimal oil supply portfolio and the best countries for oil exports are determined accordingly.

Conclusion: One of the most important concerns of most oil-exporting countries is determining the optimal oil supply portfolio because the non-commitment of buyer countries can cause serious damage to the revenue sources of exporting countries due to their high need for oil exports. In this study, the optimal oil supply portfolio is selected based on destination country and transfer risks by combining content analysis, fuzzy multi-criteria decision-making, and mathematical programming

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techniques. The proposed model suggests that the optimal oil supply portfolio can be determined. In this way, it is possible to determine how much of the export of petroleum products should be allocated to an importing country according to issues such as cost and risk. The results can be generalized to other industries. Thus, future studies can examine the proposed model for the export of other products, including mineral or agricultural products. In other words, the major importing countries can be determined, and optimal allocation to them can be made based on criteria such as risk and cost.

Keywords: multi-objective optimization, transfer risk, oil supply portfolio, destination country risk

JEL Classification: C61, Q41, G11

1. Introduction

Oil exporting countries always attach special importance to oil supply because the oil industry is the only way to realize foreign exchange income for most of them. So, it is a strategic industry for these countries (Johannesen et al., 2019). These countries always try to find stable regional and global markets for their oil exports and supply so that they are less affected by export cash return and regional and global risks (He and Lin, 2018). The single-product nature of oil economies and their reliance on oil revenues as the only way to provide foreign exchange resources make them vulnerable to sanctions and oil price fluctuations, as well as the turbulent global oil market (Bedi and Toshniwal, 2019). Clear examples of these vulnerabilities can be found in countries such as Iraq, Venezuela, and even Iran.

Unfortunately, Iran has suffered serious damage from the inability to export oil due to the presence of international pressure and sanctions, which were called maximum pressure, and were imposed on it since the Trump era and November 2018. These damages were caused by the decrease in oil exports, as well as problems in the transfer of purchased oil funds. On the other hand, these problems have been aggravated by the non-commitment of some countries that import oil from Iran, such as South Korea, which is one of the major oil importers from Iran. Besides, the problems in the transfer of funds have caused, for example, the oil exported to India to be exchanged with goods imported from that country, some of which are domestically produced and whose import is not profitable at all. According to the above, providing an optimization model for the oil supply portfolio can largely solve the problems in this field (Hao et al., 2020). Determining which countries are more economical to export to, which countries can be included in Iran's optimal export oil supply portfolio, and how much oil can be exported to them to achieve the optimal supply portfolio, considering oil transfer risk and costs, can be a major goal. This has not been investigated in any study either domestically or abroad. So, it can be argued that this is a major research gap. Accordingly, this study tries to provide a multi-objective optimization model for the oil supply portfolio, taking into account the transfer risk and the destination country risk, to solve the mentioned problems and shortcomings. In the following, a literature review is made and the study method is explained. The supply risks are then extracted based on expert opinions and weighted. In the next step, the major countries that import oil from Iran are ranked using the fuzzy VIKOR technique. Finally, the VIKOR score is entered into the mathematical programming model and the optimal portfolio is determined.

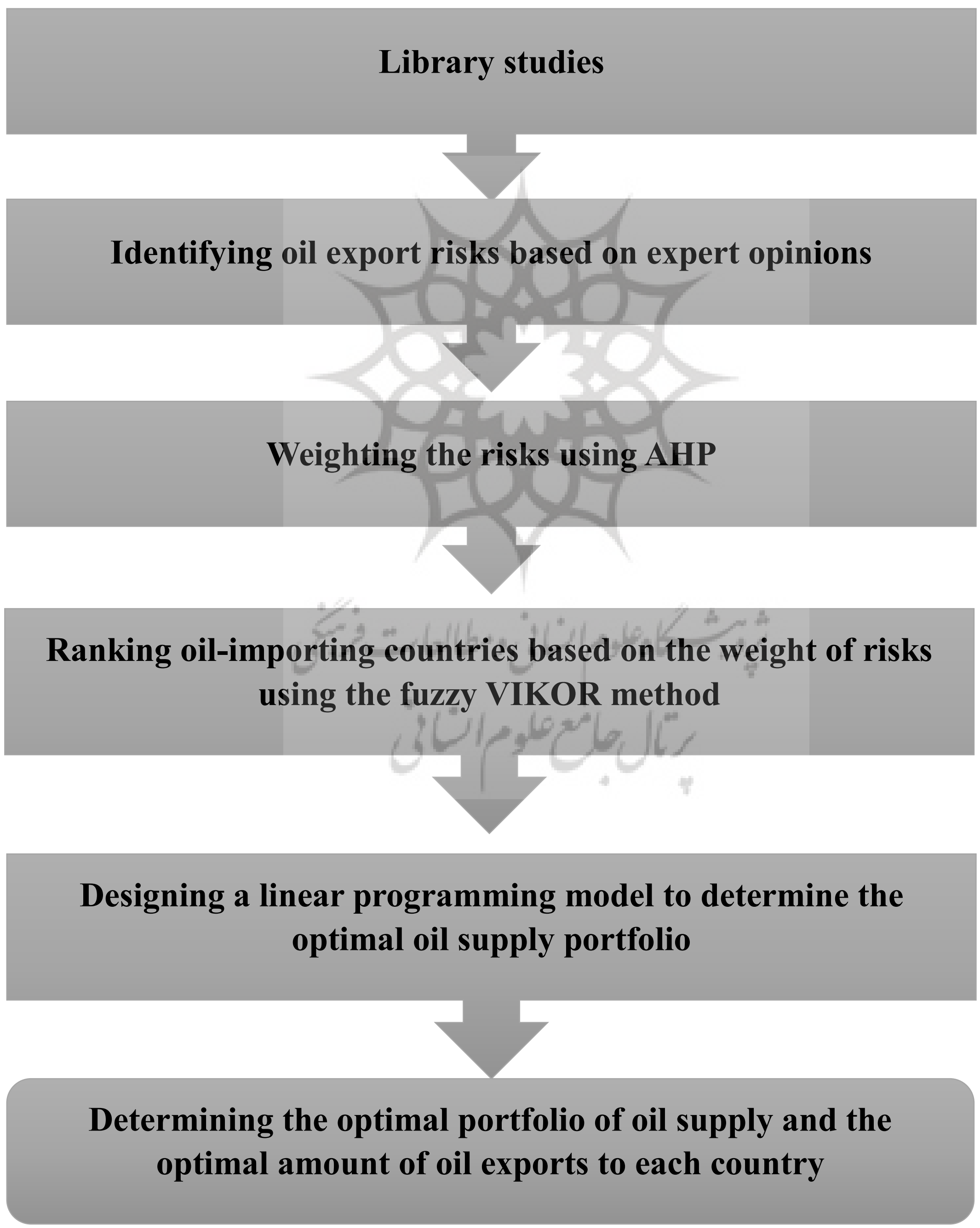
2. Literature Review

In this section, the literature on the optimization of the oil or gas supply or import portfolio is reviewed. Wang et al. (2018) investigated whether China's oil import portfolio has been continuously optimized since 2005. They first developed a multi-objective programming problem based on the choice between risk and cost and then obtained optimal results. In a study by Qi and Yang (2018), a quantitative optimization model was provided to investigate oil supply risk from the perspective of diversifying oil import sources. Nowrouzi et al. (2019) developed the concept of unsystematic risk for the natural gas dependence risk index and geopolitical risk index. They also presented a quantitative index using the cumulative entropy-based index method with appropriate sub-indices for pipeline natural gas and LNG transfer. In their study, Sehatpour and Kazemi (2018) sought to predict an optimal fuel portfolio for light vehicles in Iran based on various challenges considering the 2025 horizon.

A framework for combined upstream and downstream production planning processes using grounded theory models indicating upstream capacity, downstream processes, and the country profit model was proposed by Al-Jenaibi et al. (2019). Sun et al. (2020) presented an interval decomposition ensemble prediction model and a multi-objective programming model to support the crude oil import portfolio plan. Hao et al. (2020) identified supply risk factors and developed a supply risk assessment system from the dimensions of quality, price, delivery, service, and technology. Bigerna et al. (2021) analyzed the structure of oil imports for four Asian energy importers, namely China, Japan, Korea, and Taiwan. They measured the two-sided and overall volatility of portfolio risk associated with the composition of major oil suppliers using variance analysis of the forecast error derived from a vector autoregressive (VAR) model.

3. Methodology

This is an applied study in terms of objective and descriptive-analytical in terms of the data collection method. It is also a mixed study. The study steps are as follows.


Library studies
Identifying oil export risks based on expert opinions
Weighting the risks using AHP
Ranking oil-importing countries based on the weight of risks using the fuzzy VIKOR method
Designing a linear programming model to determine the optimal oil supply portfolio
Determining the optimal portfolio of oil supply and the optimal amount of oil exports to each country

Oil export risk is first identified based on experts' opinions and extracted using content analysis. They are then weighted using the AHP method and entered into the fuzzy VIKOR technique. In the following, the oil-importing countries are ranked using this method, and the final ranking score for each country is determined as the input parameter of the linear programming model.

3.1 Data Collection Method

The data are collected at the field and library levels. In the library section, the research gap is identified, and in the field section, oil supply risks are identified and weighted and countries are ranked using this method. The tools used are interviews with experts to determine risks, pairwise comparison questionnaires to determine the weight of risks, and fuzzy VIKOR questionnaires to determine the rank and fuzzy VIKOR score of each country, which is the input of the mathematical programming model.

3.2 Statistical Population, Sample, and Sampling Method

The statistical population includes all experts working in the National Iranian Oil Company with at least ten years of work experience, preferably in the field of export and oil contracts. Since the sample has a judgmental nature, choosing between 10 and 20 people from the statistical population leads to sample adequacy. Ten experts were selected to participate in interviews and questionnaires. Samples are people who are ready to answer the questions are selected by purposive sampling.

3.3 Mathematical Model

In this section, a mathematical model is provided to select the oil supply portfolio. Similar models mainly concern the selection of a project portfolio or stock portfolio and have similarities with the proposed model. However, the proposed model is based solely on the selection of the oil supply portfolio, that is the selection of the best countries for oil export based on two main factors, namely risk and transfer costs. The transfer costs can be extracted from the data of the National Iranian Oil Company. However, the supply risk is determined by using expert opinions AHP and fuzzy VIKOR techniques, where the final parameter is the score of the respective country from the point of view of oil transfer. Accordingly, a two-objective mathematical model is designed, with the first objective of minimizing cost and the second objective of minimizing risk. The model's assumptions are as follows.

Assumptions

1. The parameters are crisp.
2. The model is multi-period.
3. The risk level is extracted from the fuzzy VIKOR technique.
4. The oil demand of the destination country should be realized.
5. The transfer capacity is included as a parameter.

Indexes

- i: oil-importing country
- t: time

Parameters

- C_{it}: The cost of oil transfer to country i at time t
- v_i: The risk determined using the fuzzy VKOR method
- E_t: Total oil export
- cap_{ti}: The capacity of oil transfer to country i at time t
- dem_{ti}: The oil demand of country i at time t

Decision Variables

- X_{it}: 1 if country i is selected as the oil export destination at time t, and 0 otherwise

- Y_{it}: The oil transfer to country i at time t
- Z_{it}: The share of Country i of total oil exports

Objective Functions

$$\min z1 = \sum_{i} \sum_{t} C_{it} \, . \, Y_{it}$$

(1)

The first objective function seeks to minimize the transfer costs.

$$\min z2 = \sum_{i} \sum_{t} V_{i} \, . \, X_{it}$$

(2)

The second objective function seeks to minimize the transfer risk.

Constraints

$$X_{it} \leq 1$$

(3)

The above constraint indicates that each country can be selected at most once in the supply portfolio.

$$Y_{it} \geq dem_{ti}$$

(4)

Constraint 4 indicates that the amount of oil transfer should fulfill the demand of the destination country.

$$Y_{it} \leq cap_{ti}$$

(5)

Constraint 5 indicates the transfer capacity.

$$\sum_{i} Y_{it} \leq E_t$$

(6)

Constraint 6 indicates that the total amount of oil transferred to all countries cannot exceed the total amount of oil exports in the relevant period.

$$\left\{ \begin{matrix} X_{it} = 1 & Y_{it} \leq M(X_{it}) \\ X_{it} = 0 & Y_{it} \geq M(X_{it}) \end{matrix} \right\}$$

(7)

Constraint 7 indicates that if a country is not selected in the supply portfolio, oil cannot be supplied to it.

$$Z_{it} = \frac{Y_{it}}{E_t}$$

(8)

Constraint 8 shows each country's share of oil exports.

$$\sum_{i} Z_{it} = 1$$

(9)

Constraint 9 indicates that the total share of exports for all countries cannot exceed 1.

$$0 \leq Z_{it} \leq 1$$

(10)

Constraint 10 indicates the variable range of each country's share.

$$X_{it} \in \{0,1\}$$

(11)

$$Y_{it} \geq 0$$

(12)

Constraints 11 and 12 indicate the range of integer and binary variables of the problem.

3.4 The Solution Method

The problem is solved using the ε-constraint method, with the first objective being considered the main objective and the other objectives being limited to the upper bound of epsilon and applied to the problem constraints. In this case, the following single-objective model is obtained based on the ε-constraint method.

$$\min \mathrm{f1(x)}$$

$$\mathrm{fi(x)} \leq \mathrm{e_i}$$

$$\mathrm{x} \in \mathrm{X}$$

(13)

Where the first objective is considered the main objective and the second to nth objectives are limited to the maximum value of ei. In the ε-constraint method, as the values of ei change, different solutions are obtained which may not be efficient. The problem can be solved by modifying the above model. This is known as the augmented ε-constraint method. In this method, the previous equation is rewritten as follows.

$$\min f1(x) - \sum_{i=2} \phi_i s_i$$

$$fi(x) + s_i = e_i$$

$$x \in X$$

$$s_i \geq 0$$

(14)

where s_i is a non-negative auxiliary variable and ϕ_i is a parameter for the normalization of objectives. Several different values are selected and the Pareto front is obtained in this way by obtaining the outcomes matrix of the problem objectives using the lexicographic method.

3.5 Methods of Analysis

3.5.1 The AHP Technique

The analytic hierarchy process (AHP) developed by Thomas Saaty (1980) is an effective tool for complex decision-making and may help the decision-maker to set priorities and make better decisions. AHP helps to address both subjective and objective aspects of decisions by reducing complex decisions to a series of pairwise comparisons and then combining the results. Moreover, AHP includes a useful technique for checking the consistency of decision-makers evaluations. Therefore, it leads to the reduction of bias in the decision-making process.

AHP is one of the multi-criteria decision-making (MCDM) techniques first introduced by Professor Thomas Saaty. This technique is generally used to obtain relative values from ordered pairwise comparisons, eliminating some small inconsistencies in judgment because sometimes humans cannot do this.

As a decision-making process, AHP provides a comprehensive structure for combining logical and illogical visual values with a pairwise comparison method. It has been widely used in many industrial applications such as quality management, strategic planning, and policymaking. The main steps of AHP are as follows:

1. State the problem;
2. Identify the objectives of the problem considering all parameters, objectives, and outcomes;
3. Identify criteria or sub-criteria;
4. Provide a hierarchical problem structure considering objectives, criteria, sub-criteria, and a set of alternatives;
5. Develop a set of pairwise comparison matrices, which can be defined as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Where n is the matrix order.

The compatibility feature in pairwise comparisons is checked using the following method:

a) Construct the A1 matrix comparing the normal values

$$A_1 = \begin{bmatrix} a_{11}' & a_{12}' & \cdots & a_{1n}' \\ a_{21}' & a_{22}' & \cdots & a_{2n}' \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}' & a_{n2}' & \cdots & a_{nn}' \end{bmatrix},$$

$$\text{and } a_{ij'} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \text{ for } i, j = 1, 2, \ldots, \text{n},$$

b) Calculate the eigenvalue

$$w = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}, \text{ and } w_i = \frac{\sum_{i=1}^{n} a_{ij}'}{n} \text{ for } i = 1, 2, \ldots, n,$$

$$w' = Aw = \begin{bmatrix} w_1' \\ w_2' \\ \vdots \\ w_n' \end{bmatrix},$$

$$\text{and } \lambda_{\max} = \frac{1}{n}\left(\frac{w_1'}{w_1} + \frac{w_2'}{w_2} + \cdots + \frac{w_n'}{w_n}\right),$$

When w is specific, w_i is a specific value of criterion I, and max is the largest specific value of the pairwise comparison matrix.

CR > 10.0 greater than 4x4 for a matrix indicates incorrect judgment. Decision-makers should revise the original values in the pairwise comparison matrix. Use normal values to decide if a CR value of less than 10.10 is satisfactory. Although group decision-making is done in this study, this approach is to collect the opinions of a group of people. Individual judgments are summed up using the arithmetic mean method.

3.5.2 The VIKOR Technique

The VIKOR technique, an abbreviation of the Serbian phrase Vlse Kriterijumsk Optimizacija Kompromisno Resenje, is one of the MCDM models for choosing the best alternative. The model was first introduced by Serafim Opricovic in 1984. VIKOR is a compromise technique and helps to make decisions about alternatives based on different criteria. A compromise solution means the closest feasible solution to the ideal solution. Compromise is a mutual agreement.

By evaluating the alternatives based on the criteria, the VIKOR technique prioritizes or ranks them. VIKOR does not weigh the criteria but evaluates them through other methods and then evaluates and ranks the alternatives based on the criteria by combining the values of the criteria. In this model, there are always several different alternatives that are evaluated independently based on several criteria, and the alternatives are ranked based on their values.

Unlike the AHP technique or network analysis process, pairwise comparisons between criteria and alternatives are not made and each alternative is independently evaluated by a criterion in this model.

The VIKOR Technique Steps

Developing a Decision Matrix

The first step of the VIKOR technique is to develop a decision matrix, which scores each alternative based on some criteria. The decision matrix is denoted by X, and each entry is denoted by xij.

Developing a Normal Decision Matrix

The second step in solving all MCDM techniques based on the decision matrix is normalization or de-scaling. The term de-scaling should be used in MCDM methods. In the VIKOR technique, normalization is performed linearly.

Determining Positive and Negative Ideal Points

The best and the worst for each criterion are determined among all alternatives and are called f + and f -, respectively. If the criterion is utility, we will have:

$$f+ = Max\ fij$$

$$f- = Min\ fij$$

Determining Utility and Regret

Opricovic introduced the basic concepts of utility (S) and regret (R) in VIKOR calculations. The utility (S) represents the relative distance of alternative i from the ideal point, and the regret (R) represents the maximum inconvenience of alternative i from being far from the ideal point.

Calculating the VIKOR Index

The next step is to calculate the VIKOR index (Q) for each alternative.

4. Data Analysis

In this section, risks are identified and oil-importing countries are prioritized in terms of transfer costs and the destination country risk according to the methodology. The risks are first identified through interviews with industry experts and then weighted using expert opinions. In the following, the importing countries are ranked according to the weighted risks. In the next step, the optimal allocation of oil exports to each importing country is determined based on the mathematical model.

4.1 Identifying the Risks

In this section, the risks are identified according to expert opinions using content analysis. The basic themes (interviews) are located in the left column of the table below, and the sub-risks are located on the right.

Table 1. Oil export risks

Row	Risk	Basic Theme
1	Technical complications	I think the technical complications of the transfer can be known as the risk of exporting oil to the destination country. For example, the issues that must be considered during the transfer through the pipeline and are purely technical can be very effective in choosing the destination country.
2	The unpredictability of the situation	The situation is sometimes unpredictable. This can harm the right decision about choosing the destination country. So, I think this should be considered.
3	The uncontrollability of the system	The uncontrollability of the system in the destination country is sometimes an important factor. This has happened many times in oil exports.
4	Empirical risks in the industry	Some risks in the oil industry are empirical. For example, it cannot be determined in advance what such risks include.

Row	Risk	Basic Theme
		However, certain risks often occur during export by pipeline or tanker, which we have not encountered so far.
5	The lack of expertise in the destination country's technology	The lack of sufficient knowledge and technology in the destination and oil-importing countries can be a major risk. This is frequently seen in many underdeveloped countries such as African countries and some Asian countries.
6	Illiquidity	One of the most important issues in oil exports is the illiquidity of the exported oil and the non-commitment of the destination country to pay for the oil purchased. This factor should never be overlooked as a financial risk. Countries that have a relatively good track record of paying for exported oil should be chosen, and this should not be neglected.
7	Market conditions	The condition of the oil market is an important factor that must be taken into account at the time of export. Unfortunately, some countries take advantage of the crisis and special conditions in the market for their benefit and delay in fulfilling their obligations.
8	Feasibility study	Export feasibility studies should always be considered. Field studies and surveys should not be conducted properly so that export conditions can be checked in every aspect.

Row	Risk	Basic Theme
9	Variety of interests	The destination country sometimes has diverse interests or diversity of interests, which harms the conclusion of correct contracts.
10	Political risks	Political risks are among the major risks associated with oil exports. The political crises between the two countries can cause serious damage to the oil industry because it is strategic. It has been observed many times that two countries have a dispute over an issue and that this dispute causes problems in the contracts between them. A clear example is the dispute between Iran and Saudi Arabia in 2015, which led to serious problems in the trade between them.
11	Cultural and social barriers	Although cultural and social barriers may not be as important as political risks, they are not less important. Cultural and social differences between two countries can sometimes be considered an important risk in oil exports. It should be noted that this type of risk is indirect.
12	Local and regional authorities	Not only high-ranking officials of the destination country but also local and regional authorities can sometimes cause problems. This risk may not be so common but it has been observed in some cases. So, the effect of local and regional authorities is serious in some oil-purchasing countries.
13	Community opposition	The opposition of the destination community can sometimes affect the purchase of oil. Fortunately, this does not apply to

Row	Risk	Basic Theme
		Iran. However, it is an issue that should be examined as a strategic horizon in terms of the relevant responsibility.
14	Environmental risks	Environmental risks and the damage that transfer through a pipeline or oil tanker can cause to the environment, both sea and land, are among the most serious issues that are a subset of environmental issues. This should be seriously investigated with the participation of the environmental organizations of the countries of origin and destination and the oil companies of the two countries so that oil exports do not harm the destination country.
15	Pollution and losses caused by the transfer	Pollution is investigated alongside environmental issues. However, it is one of the components of environmental risks that can be examined separately and should be viewed from a serious perspective.
16	Safety	Labor safety should be taken seriously because oil and transfer industries lead to problems for the labor force. Furthermore, oil production takes place in adverse weather conditions in Iran, and the safety risk can start from the country of origin.
17	Debts	The destination country's debt must be checked. If this debt is high, the financial risk of transferring and exporting oil to this country is serious. Therefore, the conditions of the

Row	Risk	Basic Theme
		destination country in terms of debt should be taken into consideration.
18	Immunities	Diplomatic and judicial immunities and the immunities of the destination country should be checked. If a country has high immunity, they can be potential risks that will become actual risks in the long run. This should not be neglected and should be taken seriously.
19	Limitations of liability	The country of origin sometimes has limitations of liability. These are contrary to immunities. These limitations should not limit the pursuit of judicial complaints concerning the destination country.
20	Insurance rules and policies	One of the most important issues in oil transfer is insurance, which disrupts oil transfer if not taken seriously. For example, Iran's oil exports faced problems in 2012 due to the non-commitment of insurance companies to transfer oil.
21	Negligence	Negligence on the part of the authorities of the destination country, especially the Ministry of Foreign Affairs, the Ministry of Commerce, the Ministry of Energy, or the oil company is sometimes a serious issue that causes problems for exports. For example, this manifests itself technically or financially.
22	Local charges	Local charges can sometimes cause problems. For example, a local authority can claim that oil exports from the country of origin have caused damage to the area. So, the country of

Row	Risk	Basic Theme
		origin is subject to legal prosecution and can be pursued. Legal policies should prevent such charges.
23	Technology transfer	The transfer of technology to the destination country, especially a country that is not technologically advanced like African countries, can cause crises and problems in the long term.
24	Conflict of interest	The destination country sometimes decides not to import oil from a country like Iran under the pressure of a bigger country. This was evident after the November 4 sanctions imposed by Trump. Some countries preferred not to lose their interests with the US and stop importing oil from Iran. This conflict of interest was even observed among African countries. For example, Sudan, Djibouti, and Somalia preferred to cut off relations with Iran so that they could continue relations with Saudi Arabia.
25	Dispute resolution mechanism	The dispute resolution mechanism should be properly designed so that a third party can end the disputes in case of any disputes. Choosing an impartial third party is difficult. It has been observed many times that a country like Oman plays the role of a mediator between two sides of the dispute but it has mostly played a political role. The third party must be an OPEC member or an oil exporter.

As can be seen, 25 risks were identified using expert opinions. However, since these risks have many aspects, they should be placed in larger categories. So, this division is made in this section.

Table 2. Placing risks in larger categories

Technical risks	Technical complications
	The unpredictability of the situation
	The uncontrollability of the system
	Empirical risks in the industry
	The lack of expertise in the destination country's technology
Economic risks	Illiquidity
	Market conditions
	Feasibility study
Financial risks	Variety of interests
Environmental risks	Political risks
	Cultural and social barriers
	Local and regional authorities
	Community opposition
	Environmental risks
	Pollution and losses caused by the transfer

Operational risks	Safety
Contractual legal risks	Debts
	Immunities
	Limitations of liability
	Insurance rules and policies
	Negligence
	Local charges
	Technology transfer
	Conflict of interest
	Dispute resolution mechanism

By assigning each risk to a related and larger category, a total of 6 general risks are identified, as given in the table above.

4.2 Weighing the Risks

After the risks are identified, they are weighted using the AHP technique. The identified risks are quantitative and weighted by experts based on pairwise comparison questionnaires. The results of the analysis can be seen in the figures and tables below.

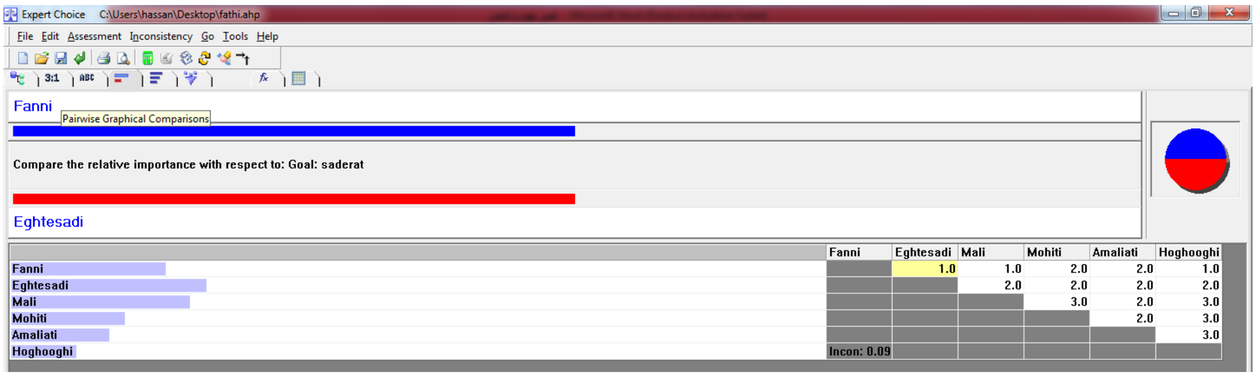


Figure 2. The risk decision matrix

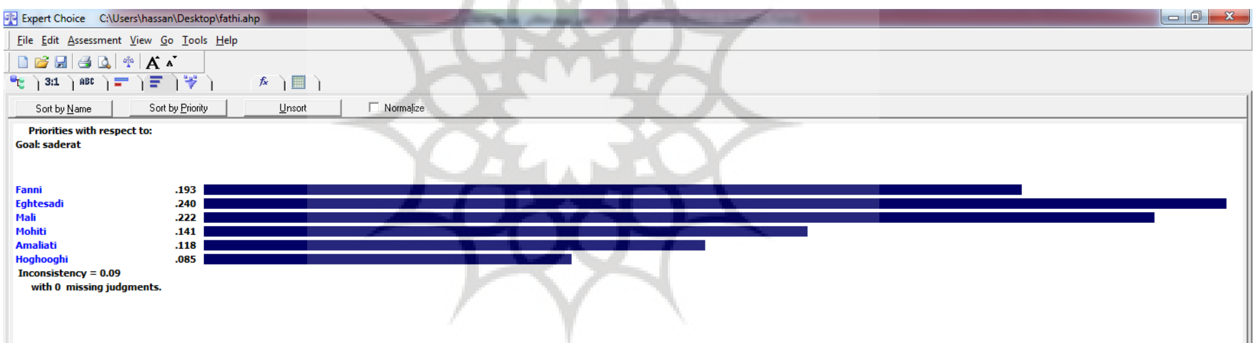


Figure 3. Expert Choice output to determine the importance of the risks

Table 3. The final weighting of the identified risks

Row	Risk	Notation	Score
1	Technical	R1	0.193
2	Economic	R2	0.240

3	Financial	R3	0.222
4	Environmental	R4	0.141
5	Operational	R5	0.118
6	Legal	R6	0.085

Based on the above table, the importance and weight of each risk is identified and it is determined which risk has more weight and importance. In this section, the countries that import oil from Iran are ranked using the weight of risks. So, the identified weights are important only in this sense.

4.3 Ranking of Importers by Risk

In this section, the 10 countries that import oil from Iran and are identified by experts are ranked. The countries are as follows:

Table 4. The countries participating in the study

Row	Country	Notation
1	China	A1
2	India	A2
3	South Korea	A3
4	Turkey	A4
5	Italy	A5

6	Japan	A6
7	France	A7
8	Greece	A8
9	UAE	A9
10	Spain	A10

In this way, the ten countries are presented in terms of oil import history as described above, and their notation is introduced in the fuzzy VIKOR technique, which is used to prioritize the countries according to the 6 risks determined.

Accordingly, the fuzzy decision matrix for the VIKOR technique is developed as follows.

Table 5. The fuzzy decision matrix for the VIKOR technique

	R1			R2			R3			R4			R5			R6		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
A1	1	3	4	2	4	5	1	1	3	5	5	6	2	4	5	2	3	3
A2	2	3	4	2	3	4	2	2	2	4	5	5	2	3	4	1	3	4
A3	2	4	3	3	5	4	2	3	4	5	5	5	4	5	6	2	3	3
A4	1	3	4	2	5	5	3	4	4	3	3	4	3	4	4	2	2	2
A5	2	2	3	3	4	5	4	5	5	2	2	3	2	3	3	3	4	5
A6	3	3	3	2	4	6	4	5	6	3	3	1	1	2	3	3	3	3
A7	4	3	3	3	4	6	3	3	4	2	2	3	1	2	3	4	5	6
A8	3	3	4	2	3	6	2	3	4	3	3	3	2	3	3	3	3	5
A9	4	4	4	1	2	4	3	3	3	2	3	3	5	5	6	2	3	4

A10	4	4	4	2	2	3	1	2	3	4	5	6	4	5	5	4	5	5

The positive and negative ideal solutions are calculated after developing the fuzzy decision matrix.

Table 6. Positive and negative ideal solutions

	0.193			0.24			0.222			0.141			0.118			0.085		
Positive ideal solution	4	4	4	3	5	6	4	5	6	5	5	6	5	5	6	4	5	6
Negative ideal solution	1	2	3	1	2	3	1	1	2	2	2	1	1	2	3	1	2	2

After obtaining the positive and negative ideal solutions, the distance to the ideal point is calculated for each fuzzy number as described in the table below.

Table 7. The distance of each fuzzy number to the ideal point

	R1			R2			R3			R4			R5			R6		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
A1	-3	-1	0	-1	1	2	-3	-3	-1	0	0	1	-3	-1	0	-2	-1	-1
A2	-2	-1	0	-1	0	1	-2	-2	-2	-1	0	0	-3	-2	-1	-3	-1	0
A3	-2	0	-1	0	2	1	-2	-1	0	0	0	0	-1	0	1	-2	-1	-1
A4	-3	-1	0	-1	2	2	-1	0	0	-2	-2	-1	-2	-1	-1	-2	-2	-2
A5	-2	-2	-1	0	1	2	0	1	1	-3	-3	-2	-3	-2	-2	-1	0	1
A6	-1	-1	-1	-1	1	3	0	1	2	-2	-2	-4	-4	-3	-2	-1	-1	-1
A7	0	-1	-1	0	1	3	-1	-1	0	-3	-3	-2	-4	-3	-2	0	1	2
A8	-1	-1	0	-1	0	3	-2	-1	0	-2	-2	-2	-3	-2	-2	-1	-1	1
A9	0	0	0	-2	-1	1	-1	-1	-1	-3	-2	-2	0	0	1	-2	-1	0

A10	0	0	0	-1	-1	0	-3	-2	-1	-1	0	1	-1	0	0	0	1	1

In the following, the weighted matrix of the VIKOR technique is obtained.

Table 8. The weighted matrix of the VIKOR technique

	R1			R2			R3			R4		
	L	M	U	L	M	U	L	M	U	L	M	U
A1	0.579	0.04825	0	0.11	-0.03429	-0.06	0.333	0.666	0.074	0	0	-0.02014
A2	0.193	0.04825	0	0.24	0	-0.04	0.111	0.148	0.222	0.03525	0	0
A3	0.128667	0	0.193	0	-0.06857	-0.048	0.222	0.074	0	0	0	0
A4	0.579	0.04825	0	0.12	-0.08	-0.096	0.074	0	0	0.0705	0.0564	0.0282
A5	0.128667	0.193	0.0965	0	-0.06	-0.12	0	-0.02775	-0.02775	0.10575	0.0846	0.0564
A6	0.04825	0.04825	0.0965	-0.24	-0.06	-0.144	0	-0.03171	-0.0555	0.040286	0.040286	0.141
A7	0	0.064333	0.0965	0.14	-0.048	-0.10286	0.074	0.037	0	0.10575	0.0705	0.047
A8	0.064333	0.04825	0	-0.24	0	-0.10286	0.222	0.0444	0	0.0564	0.047	0.0564
A9	0	0	0	0.15	0.08	-0.048	0.0555	0.037	0.0444	0.10575	0.094	0.094
A10	0	0	0	0.12	0.048	0	0.333	0.148	0.074	0.047	0	-0.0235

The utility (S) and regret (R) indices, which are the prerequisites for calculating the Q index, can be obtained based on the weighted matrix.

Table 9. Calculation of utility and regret indices

Country	S			R		
A1	0.912	0.71425	0.074	0.343667	0.013714	-0.05181
A2	0.304	0.19625	0.222	0.64825	0.067667	-0.0164
A3	0.350667	0.074	0.193	0.096	-0.04024	-0.03652
A4	0.653	0.04825	0	0.292	0.081067	0.036867
A5	0.128667	0.16525	0.06875	0.23675	0.0836	-0.00193
A6	0.04825	0.016536	0.041	-0.02113	0.126619	0.084333
A7	0.074	0.101333	0.0965	0.403083	0.1825	0.03381
A8	0.286333	0.09265	0	-0.0526	0.134333	-0.00446

A9	0.0555	0.037	0.0444	0.34075	0.202333	0.029143
A10	0.333	0.148	0.074	0.1965	0.031	-0.0405

The Q index, which is the basis of prioritization, can be calculated by obtaining the utility (S) and regret (R) indices.

Table 10. Calculation of S and R indices

Country	Q index		
A1	0.251133	-0.14559	-0.00444
A2	0.19045	-0.05278	-0.04112
A3	0.089333	0.006752	-0.0313
A4	0.189	0.025863	-0.00737
A5	0.073083	0.04977	0.013363
A6	0.005424	0.028631	0.025067
A7	0.095417	0.056767	0.026062
A8	0.046747	0.045397	0.000891
A9	0.07925	0.047867	-0.01471
A10	0.1059	0.0358	-0.0067

The final de-fuzzified score should be obtained as described in Table 11 by de-fuzzing the Q index.

Table 11. The de-fuzzified score

The de-fuzzified score	Country	Alternative
0.01112	China	**A1**
0.010941	India	**A2**
0.017886	South Korea	**A3**
0.058338	Turkey	**A4**
0.046497	Italy	**A5**
0.021938	Japan	**A6**
0.058753	France	**A7**
0.034608	Greece	**A8**
0.040069	UAE	**A9**
0.0427	Spain	**A10**

Based on the above table, the de-fuzzified scores are calculated. The scores can be used to obtain the final ranking of the countries according to the table below.

Table 12. The final ranking of the countries

Ranking	Final score	Country	Alternative

1	0.059	France	**A7**
2	0.058	Turkey	**A4**
3	0.046	Italy	**A5**
4	0.043	Spain	**A10**
5	0.04	UAE	**A9**
6	0.035	Greece	**A8**
7	0.022	Japan	**A6**
8	0.018	South Korea	**A3**
9	0.011	China	**A1**
10	0.011	India	**A2**

France has the lowest known risk, followed by Turkey, Italy, and Spain. The countries with the highest oil export risk are India, China, and South Korea, respectively. In the following, the weights obtained from the fuzzy VIKOR technique are entered into the mathematical model and act as input parameters.

4.4 Determining the Optimal Oil Supply Portfolio

So far, oil export risks have been identified and weighted, and countries have been prioritized accordingly. In this section, optimal amounts of exports are allocated to each country. By solving the mathematical model in GAMS software, the optimal amount of export allocation at any time for each country is as follows.

Table 13. The optimal amount of oil export allocation to importing countries by time

Country	1	2	3	4	5	6	7	8	9	10	11	12
China	53	61	60	55	53	68	65	51	74	79	68	68
India	61	68	71	65	54	70	66	53	80	57	70	74
South Korea	78	56	59	56	57	70	72	52	54	63	55	71
Turkey	73	54	62	71	76	68	80	50	55	52	66	53
Italy	72	53	65	74	65	66	50	66	63	80	55	55
Japan	50	55	51	50	75	68	50	56	79	60	68	58
France	69	54	64	62	74	66	62	67	78	60	50	79
Greece	67	60	80	73	53	80	67	55	69	60	78	77
UAE	50	61	70	68	51	76	78	65	59	65	51	73
Spain	66	73	72	69	53	80	71	80	76	69	71	71

As can be seen, the optimal amount of allocation and the optimal portfolio of oil exports to the countries are identified for 12 months. These amounts are due to the costs and the risk of the destination countries. Each country's share of total exports is given below.

Table 14. The percentage of optimal allocation of oil exports to importing countries by time

Country	1	2	3	4	5	6	7	8	9	10	11	12
China	0.0265	0.0305	0.03	0.018333	0.017667	0.030222	0.0325	0.0255	0.037	0.026333	0.022667	0.030222
India	0.0305	0.034	0.0355	0.021667	0.018	0.031111	0.033	0.0265	0.04	0.019	0.023333	0.032889
South Korea	0.039	0.028	0.0295	0.018667	0.019	0.031111	0.036	0.026	0.027	0.021	0.018333	0.031556
Turkey	0.0365	0.027	0.031	0.023667	0.025333	0.030222	0.04	0.025	0.0275	0.017333	0.022	0.023556
Italy	0.036	0.0265	0.0325	0.024667	0.021667	0.029333	0.025	0.033	0.0315	0.026667	0.018333	0.024444
Japan	0.025	0.0275	0.0255	0.016667	0.025	0.030222	0.025	0.028	0.0395	0.02	0.022667	0.025778
France	0.0345	0.027	0.032	0.020667	0.024667	0.029333	0.031	0.0335	0.039	0.02	0.016667	0.035111
Greece	0.0335	0.03	0.04	0.024333	0.017667	0.035556	0.0335	0.0275	0.0345	0.02	0.026	0.034222
UAE	0.025	0.0305	0.035	0.022667	0.017	0.033778	0.039	0.0325	0.0295	0.021667	0.017	0.032444
Spain	0.033	0.0365	0.036	0.023	0.017667	0.035556	0.0355	0.04	0.038	0.023	0.023667	0.031556

The Pareto points for the problem are examined to find the optimal solution.

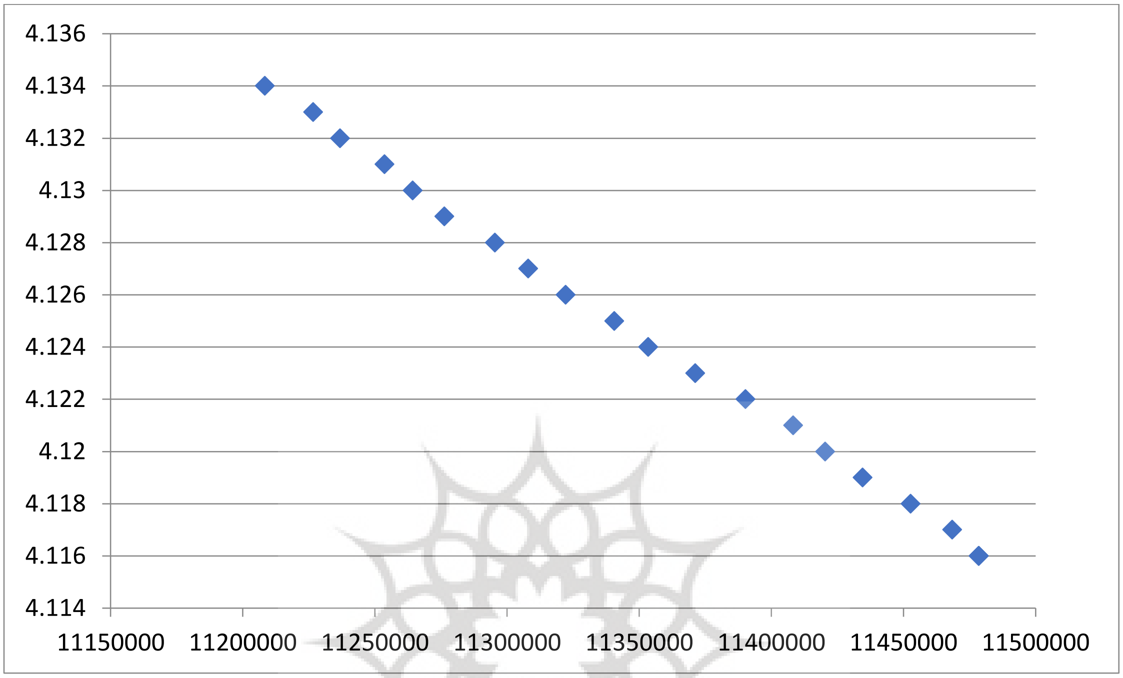


Figure 4. The Pareto chart of the problem

In the figure above, there is an inverse relationship between two objective functions, i.e., risk and cost. As the cost increases, the risk can be reduced and vice versa. Accordingly, it can be argued that the solution method can solve the provided mathematical programming model. So, the results are reliable.

5. Conclusion

In this study, the optimal oil supply portfolio is selected based on destination country and transfer risks by combining content analysis, fuzzy multi-criteria decision-making, and mathematical programming techniques. The proposed model suggests that the optimal oil supply portfolio can be determined. In this way, it is possible to determine how much of the export of petroleum products should be allocated to an importing country according to issues such as cost and risk. The results can be generalized to other industries. Thus, future studies can examine the proposed model for the export of other products, including mineral or agricultural products. In other words, the major importing countries can be determined, and optimal allocation to them can be made based on criteria such as risk and cost. It should be noted that future studies can use other techniques for this purpose. For example, they can use data mining techniques such as feature determination to categorize identified risks or factors to enrich their methodology or use other criteria such as quality or resilience.

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