FUZZY OPTIMIZATION AND MODELLING 4(3) (2023) 72-91
E-ISNN: 2676-7007

Contents lists available at FOMJ

Fuzzy Optimization and Modelling

Journal homepage: http://fomj.qaemiau.ac.ir/

Paper Type: Research Paper

Futures Studies of Gas Industry in Iran based on Fuzzy MCDM Methods and Critical Uncertainty Approach

Mohammad Reza Fathi[a], Abolfazl Khosravi [*b], Somayeh Razi Moheb Saraj[c], Amirhossein Behrooz[d]

[a] Department of Management and Accounting, College of Farabi, University of Tehran, Qom, Iran
[b *] Department of Management and Accounting, College of Farabi, University of Tehran, Qom, Iran
[c] Department of Management and Accounting, College of Farabi, University of Tehran, Qom, Iran
[d] Payame Noor University, Iran

A R T I C L E I N F O

Article history:
Received 30 June 2023
Revised 18 November
Accepted 19 November
Available online 19 November 2023

Keywords:
Futures Studies
Gas Industry
Critical Uncertainty Approach,
Fuzzy DEMATEL
Scenario Planning

A B S T R A C T

Huge gas resources are one of the main factors influencing Iran's overall economic policy and can define an effective strategy for overcoming existing crises and sanctions. Therefore, the present study seeks to identify the Iranian gas industry's key factors and plausible scenarios in the future. This study is applied research. Therefore, by examining the theoretical foundations and interviewing experts, the key factors affecting the gas industry's future were identified. Then, these factors were screened using a binomial test. Both critical uncertainty and Fuzzy DEMATEL techniques were used to select the final drivers. The probabilistic scenario was also selected using the Fuzzy MOORA technique. International sanctions and pressures and technological learning were selected as the two drivers for scenario mapping using the critical uncertainty and Fuzzy DEMATEL techniques. Based on the results, four scenarios of "Gas Industry Paradise," "Oppressive World," "Abandoned Island," and "Gas Industry Hell" were developed. Each of these scenarios represented a situation for the future gas industry. According to the criteria of trend alignment, reality-based probability, and consistency with current data, the "Oppressive World" was selected as the most probable scenario. The "Gas Industry Paradise" scenario showed the best situation for relieving foreign sanctions and technological learning in the gas industry. On the other hand, the "Gas Industry Hell" scenario described an isolated and vulnerable system to threats.

[*] Correspondig author

E-mail address: khosravi_a@ut.ac.ir (Abolfazl Khosravi)

DOI: 10.30495/fomj.2023.1990204.1101

1. Introduction

Today, any good decision-making requires information and knowledge about the future [1]. "The future can be predicted with the help of the past" is a quote from Edward Cornish, a well-known futurist who states the purpose of futures studies in one sentence. The rapid growth of information and communication technologies requires every organization to formulate a strategic plan to deal with the future. Due to this necessity, a new knowledge called futures studies was formed to clarify the ambiguous future scientifically and systematically. In the face of changes that will occur in the future, two passive and active reactions can be shown. In passive reaction, the organization is receptive to any form of change. Crises resulting from these changes can provide grounds for weakness or bankruptcy of the organization. Unknowingly and ignorantly facing the future can certainly be associated with harm. For active response, the organization, with knowledge and awareness of new events, prepares itself to cope with the crises caused by change and consciously faces change. With this insightful approach, the organization can even turn threats into opportunities. The ultimate goal of futures studies is the design and architecture of the desirable future. Futures studies can help people recover their organization and create a world in which they are interested in living [6].

Future scenarios profoundly affect human thinking and the decision-making process and can help initiate a public debate. The SP also stimulates thinking about the future and challenges the current situation with a possible plan [3]. SP is used effectively to explore and build potential futures based on existing social, environmental, economic, and cultural stimuli in informing decision making [8]. A “Scenario” gives future studies a methodological unity, and almost all futurists use it somehow. The scenario is the most widely used methodological tool in futurism, and it is a technique that is mostly used in futures studies [39].

The gas industry is one of the industries that has benefited from this knowledge.

Energy carriers play a crucial role in the national and international economies. These carriers have a very significant impact on the Iranian economy from three perspectives. First, they are used for lighting, heating, cooling, and cooking. Second, they provide the fuel needed by the country's economic and manufacturing sectors, such as agriculture, industry and mining, and services. Moreover, third, the role of energy exchange through the export of crude oil and gas is of great importance. In practice, government budget and private sector activities are directly dependent on foreign exchange earnings from the country's oil and gas exports. Today, as an energy carrier, gas has found a special place in the world's energy portfolio, so that the 21st century has been called the gas century [31]. Iran is also one of the world's major oil and gas producers with 153.8 billion barrels of crude oil and 33.5 billion cubic meters of gas reserves, accounting for 9.3% and 18% of the world's total oil and gas reserves, respectively. Along with a special geographical location, rich hydrocarbon reserves are one of Iran's main competitive advantages [25].

According to most energy experts, fossil fuels will play a crucial role in meeting the world's energy needs for at least the next two decades. Based on the widespread use of gas and increased investment in developing gas fields, the development of new gas exploitation technologies, and the expansion of gas distribution and transmission networks around the world, we can consider the next two decades as gas dominance in the global energy market [34, 42, 28]. According to forecasts by the International Energy Agency, between 2012 and 2035, gas demand will increase by about 80%, reaching 4.5 trillion cubic meters [34]. Also, according to forecasts (Figure 1), the pattern of global consumption and countries' reliance on gas is changing. For example, in 2035, the United States will become a gas exporter, but gas imports from many countries, including China and India, will increase by 20% [34, 42]. Therefore, examining the conditions of major countries in this industry, including Iran, to supply the world’s gas can be effective on the futures studies of this industry.

Recently, planning for the fossil energy sector, which has been the main source of income for the Iranian economy for many years, has been hampered by sanctions from the Security Council, the United States, and the European Union.

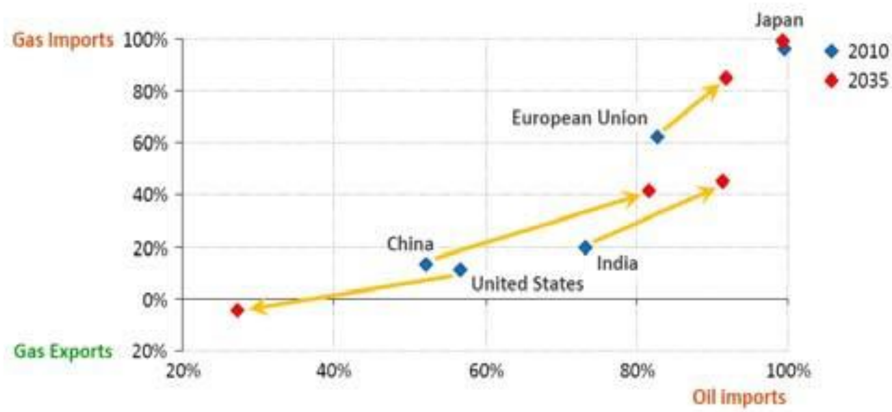

Figure 1. Dependence on oil and gas imports in some countries [34]

Iran’s oil and gas sector faces limitations at various levels from investment to sales, the presence or absence of which can cause major changes in energy sector policy. In addition, the need to take into account the uncertainties inherent in the field of energy makes it necessary to use alternative futures rather than a definite future to develop the strategy. This issue has received less attention in previous research. Most of the studies conducted on the Iranian gas industry have only examined a part of this industry. No study covers the whole industry and includes all the factors affecting the gas industry, nor has there been any study that specifically deals with futures studies in the gas industry. One of the study's contributions is identifying the components affecting the gas industry and presenting the scenarios ahead.

This study intends to create and develop alternative scenarios for the Iranian natural gas industry using the scenario planning method based on key uncertainties. Accordingly, the study seeks to identify key drivers and factors affecting the Iranian natural gas industry. Once these drivers are identified, the various futures that await the industry can be identified. Developing plausible natural gas industry scenarios helps key stakeholders and actors develop flexible plans to prepare for different situations. The following are the research questions.

• What are the influential drivers on Iran's gas industry?
• What are the plausible scenarios for the Iranian gas industry?
• What is the ranking of plausible scenarios of Iran's gas industry?

2. Literature Review

Futures research is equivalent to the word "futures studies." The plural term "futures" is used because it uses many methods to make systematic and rational assumptions about not just one future but several futures. Futures studies topics include possible, probable, and optimal species for transformation from the present to the future.

In a deeper sense, futures studies are the science and art of discovering the future and shaping the desirable world of tomorrow [5]. Scenario planning is an important tool for foresight and futures studies. The term "scenario" is used to describe a wide range of concepts, from the simple expression of an alternative to the result of complex simulation models. Peter Schwartz defined a scenario as a tool for regulating an individual's perception of possible future environments in which decisions will be made [38]. What the future may turn out to be is not a prediction but a possible outcome of the future [7]. The following are some of the research done in futures studies and the gas industry.

In a study "Resistance Economy in the Gas Industry," Tari et al [40] stated that despite various sanctions, the current economic situation is one of the most critical economic conditions for the Islamic Republic of Iran. The sanctions imposed on Iran by the United States, and these sanctions are increasing day by day, have caused economic anomalies. Hence, the resistance economy proposed by the Supreme Leader in 2010 is based on the goal that growth and prosperity can be achieved despite sanctions. This prosperity means supporting the country's domestic products and resources. Meanwhile, one of the resistance economy dimensions in the gas industry is one of the most important energy carriers. Traditionally, oil revenues and energy carriers have led to a failure in non-oil revenues. The goal of the resistance economy in developing the gas industry is to prevent the sale of raw materials and the proper use of gas in infrastructure. Given the above, it can be acknowledged that the resistance economy can only succeed if the level of support for domestic production and human resources increases, thereby reducing the country's dependence on oil revenues.

Samadi and Eydizadeh [32] conducted a study entitled "Designing a Dynamic Model for Iran Gas Industry: A System Dynamics Approach" to assess the current state of the Iranian gas industry and develop appropriate policies to achieve the objectives of the Iranian Vision document in 2025 horizon. For achieving this goal, a dynamic model including three subsystems of exploration, production and consumption, and demand was designed based on the system dynamics approach and simulated for the period 2010-2025. In this model, the factors affecting gas exploration, gas demand, and consumption and factors affecting the production, export, import, and share of other fuels in the energy supply were identified. The dynamic interrelationships between them were also investigated. The results of solving the basic model showed that by continuing the current policies, we would not achieve any of the goals of the vision document (except for the goal of 75% share of gas consumption).

Accordingly, new policies were developed and incorporated into the model in the form of some protocols. The simulation results of the protocols showed that in order to achieve the intended goals in the gas industry, besides coordination in the sub-sectors of the gas industry, production and exploration rates must be increased, and significant technological advances in exploration and production must be made. The use of renewable or clean energy sources, such as hydro, wind, and solar sources, should also be increased to provide domestic consumption. The results of the model validation tests also indicated that the model had an acceptable validity. Fathi et al [13] investigated the future of investment and financing of rail transportation industry. with analysis of Scenario wizard software, 5 scenarios with high consistency presented and then with regard to expert's viewpoints, 2 effective key factors including economic sanctions and monetary and financial policies that have high uncertainty and high importance, identified as pivots of writing future scenarios and then 4 scenarios for future of investing and financing in railway transportation industry presented.

In their study, "Future Scenarios for Downstream Projects in Iran's Oil, Gas and Petrochemical Industries," Naqdibak and Keramati [26] used the scenario building technique as one of the tools of futures studies to draw a picture of possible futures for these projects. Accordingly, in this paper, they presented four scenarios: "Gray," "Victim," "Fire," and "Rainbow". Fathi et al [11] investigated the future of Spiritual Tourism based on Cross Impact Matrix and Soft Systems Methodology. In this study, by studying the literature and interviewing with experts, the factors influencing the future of spiritual tourism were identified and then, using the Cross Impact analysis approach, the data was entered into the MIC MAC software and two key factors affecting the future of spiritual tourism in Qom province. It was found out that Facilitate versus Rigor and Culture policy which were selected among the eleven final effective factors. In the next step, four scenarios are presented in this study. Shahbazi [37] conducted a study entitled "Iranian oil and gas industry prospect in the horizon of 2025: do's and don'ts". In this study, referring to the prospects of the Iranian oil and gas industry in the horizon of 2025 and the main tasks of the Ministry of Petroleum to apply the principle of national ownership and sovereignty over reserves, he sought to mention some of the challenges ahead to achieve the vision of the Iranian oil and gas industry in the horizon of 2025 and the strengths and weaknesses, i.e., the dos and don'ts of the country's management system.

In their research, "Evaluation of Strategic Plans in the Development of Iran's Gas Industry," Atef et al [4] sought to estimate gas resources and evaluate gas supply and demand until 2016 and examine the potential for profitability in production surplus on consumption according to available infrastructure. According to the results of reviewing the proposed solutions in the field of gas converting industries and the ratio of investment and income, Iran will increase its production from 8.7% to 9.8% by building two methanol units from 19% to 25% of the world's methanol production and by building two gas conversion units to olefin. In addition, with the construction of 3 LNG units, Iran's production capacity will reach 52 million tons per year by 2015. With the increase of injection capacity to oil fields to 58.22 million cubic meters per day, oil production will increase from 4 million barrels to 4.4 million barrels per day. These studies predict that non-OECD countries will have the highest supply and demand by 2030. Soleymani Sarvestani et al [33] investigated the future of Iran Handmade Carpet Industry Using Critical Uncertainty Approach. According to the results of the GBN, the final key factors are: boom or recession in consumer countries, monetary and exchange rate policies, government support facilities, foreign sanctions, marketing, use of advanced technology in raw materials production, The boom or recession in Iran, export support method and the organizing approach of supply chain stages.

In a study, "robustness of gas industry development plans and strategies using futures studies," Shamaei et al [36] tried to investigate a case study (gas industry development strategies) using a robust planning method and present the results. They analyzed these strategies, which are 67 strategies considered by the country's gas industry, using the robust planning technique. Finally, they provided some recommendations for their robustness in various scenarios facing the country's gas industry. Kashanipour et al [23] investigated the future of Sustainability Reporting Using Scenario Planning Approach. Initially, factors affecting sustainability reporting were extracted by reviewing the research background and interviewing 29 academic and professional experts. From 45 extracted factors, 20 factors were identified as significant factors based on expert questionnaire. Then, three factors were identified using cross-effects impact analysis and Mic Mac: legal requirements, climate and environmental crises, and the existence NGO as key drivers affecting future of sustainability reporting. Finally, according to the experts ('39') opinions, four scenarios for the future of sustainability reporting were formulated and suggestions were made for each other. Maleki et al [24] investigated the future of Religious Tourism of Qom Province based on Scenario Planning Approach. The believable scenarios of the present study were based on the two uncertainties of foreign sanctions and the development of the city based on the competitive advantage.

In their study, Fathi et al. [10] conducted operations research's futures studies with a scenario planning approach. The study's researchers developed the exploratory scenarios of operations research knowledge using the critical uncertainty approach. In order to develop plausible scenarios of operations research, the opinions of domestic and foreign experts in this field were collected with the Delphi approach and through uncertainty questionnaires. Then, plausible operations research scenarios were written with the help of experts through brainstorming workshops.

In a study, "Mapping futures studies scholarship from 1968 to present: A bibliometric review of thematic clusters, research trends, and research gaps", Fergnani [18] provides a comprehensive and objective review of academic activity in future studies from its origins, i.e., from 1968 to the present, and suggests some ways to improve it by articulating the research gap in this time frame. Ahmadi et al [2] investigated the future of Oil Industry with Scenario Planning Approach. Using GBN and DEMATEL techniques, two key forces of external sanctions and macroeconomic policies related to strengthening were selected for mapping the scenarios. Based on these two key forces, the four scenarios of closed supply chain, fragile supply chain, robust supply chain and dynamic supply chain were developed. Jandaghi et al [21] identified the plausible scenarios of tourism in Turkey. For this purpose, the drivers and key factors of the research were first identified by reviewing the literature and interviewing Turkish tourism experts. Then these factors were screened using binomial nonparametric test and eight factors were eliminated from the 19 key factors. Two key factors of government policy in the tourism field and value of country currency were selected using cross impact analysis technique in order to write plausible scenarios. Based on these two uncertainties, four scenarios of luxury tourism, cheap tourism, tourism deterioration and unplanned tourism were identified.

3. Research Methodology

The present study is applied in terms of orientation, and it is methodologically multiple. In this study, quantitative methods including critical uncertainty, Fuzzy DEMATEL and Fuzzy MOORA are used to investigate the problem, all of which belong to the positivist paradigm. Also, since all of these methods are quantitative and belong to the same paradigm, the research methodology is multiple. The study aims to develop plausible and probable scenarios for the future of the gas industry. Therefore, by reviewing the research literature and surveys of experts in this field, the factors affecting the future formation of Iran's gas industry were identified.

These drivers were then screened using a binomial test to select the main factors. After removing the non-key factors, using the critical uncertainty technique and Fuzzy DEMATEL, the final drivers were selected to develop plausible scenarios. Plausible scenarios are possible scenarios that seem logical and rational in terms of current human knowledge. Then, each of the methods used in the research is briefly described. Critical uncertainty is one of the most common approaches for scenario development. In this method, key factors are evaluated according to three indicators: degree of expertise, importance, and consensus. The greater the degree of expertise in the driver in question, the more important that driver is in shaping the future of the subject matter. The fewer consensuses exist on that driver; the more priority driver or uncertainty has for developing plausible scenarios. After determining the key drivers according to the three indicators, plausible scenarios are described based on expert opinions [38]. To further validate the results of research uncertainties, the Fuzzy DEMATEL technique evaluates drivers or uncertainties. Finally, the Fuzzy MOORA technique is used to select a possible scenario.

Fuzzy DEMATEL is one of the structural modeling and analysis techniques evaluating the causal relationships between complex factors. This technique was first used at the BMW Institute in Switzerland between 1972 and 1976 in a project implemented at the Geneva Research Center. Using graph theory, the Fuzzy DEMATEL extracts the interactions of the influence and dependence of the elements in a way that confirms the intensity of the effect of the relations as a certain numerical score and also the dependence between the goals according to the intrinsic characteristics of factual matters [41]. The Fuzzy MOORA is one of the decision-making techniques used to rank alternatives. Each of the critical uncertainty techniques has its standard Fuzzy DEMATEL questionnaires, so the validity and reliability of the study are confirmed. Foresight projects and studies typically use the critical uncertainty technique to identify key drivers for mapping scenarios. However, this study uses the Fuzzy DEMATEL soft technique to complete the critical uncertainty method. The Fuzzy DEMATEL is an efficient method for extracting key factors by discovering the causal relationships of variables and determining the most influential factors. This study first selects five key factors using the critical uncertainty approach and applying the expertise, importance, and consensus indicators. The final uncertainties are then selected using the Fuzzy DEMATEL technique. One of the new decision-making techniques commonly used for ranking is employed to select a possible scenario.

4. Analysis

Extraction of Final Drivers

In this section, the drivers of the future formation of the gas industry were identified by reviewing the literature and interviewing experts. Screening methods such as binomial tests were used to select the final uncertainties. First, factors with a score lower than the mean were eliminated through this test. Then, using both critical uncertainty and Fuzzy DEMATEL methods, the factors that obtained the necessary scores in both methods were considered the final uncertainties for scenario planning. In order to make the final selection, the key factors must have obtained the necessary scores in three indicators of expertise, importance, and consensus from the perspective of critical uncertainty and the net effect index from the perspective of the Fuzzy

DEMATEL technique. Ultimately, the outcome of these two methods will determine the final uncertainties. Due to the high frequency of drivers, the Likert scale questionnaire was used to reduce drivers. The designed questionnaire included 42 items of factors affecting the future of the gas industry. Sixteen experts completed the questionnaire. Then, the appropriate statistical test was used. Based on the results, some drivers were removed. The Wilcoxon test was used to determine the reliability of the outputs. The final factors are listed in Table 1.

Table 1. Final factors screened

Factors affecting the gas industry	Source
International sanctions and pressures	[41, 26, 34, 17, 14, 22]
Investment (financial resources)	[37, 26, 31, 34, 20, 15, 17]
Technological learning	[27, 37, 32, 31]
Export capacity	[32, 29, 34]
Exploration level	[32, 29, 34, 31]
Gas prices	[32, 26, 34]
gas production capacity	[29, 34, 31, 32]
Storage capacity	[29, 34]
Internal consumption	[29]
Powerful competitors	[37]
Specialized human resources	[37]
Development and optimization plans	[34, 26]
Gas infrastructure	[26]
Supplies and equipment	[40]
Research and knowledge bases	[40]
Government's domestic and foreign policies	[26]
Demand rate	[26, 34, 16]
Exchange rate	[26]
Regional crisis	[34]

In the following, the collected data will be explained as compiled data. The results of data analysis are presented in separate tables, including expertise index, importance index, and consensus index. Data are collected in two steps using the Delphi method.

Determine critical uncertainties using the expertise index

This indicator shows how much an expert in a field specializes in a proposition or question. The expertise index is calculated as follows:

$$\textbf{Expertise index} = \frac{\text{Number of answers to option (a)}*100+\text{Number of answers to option (b)}*50+\text{Number of answers to option (c)}*25+\text{Number of answers to option (d)}*0}{\text{Total number of answers}} \quad (1)$$

The closer the expertise index is to zero; the less specialized knowledge experts have on the subject. The closer the index is to 100, the more specialized knowledge the experts have on the subject. Table 2 shows some of the drivers that experts are more knowledgeable about them. According to the results, it is observed that the expertise index for all propositions is above 50. Therefore, it can be stated that the experts' knowledge level in the field in question is moderate to high.

Table 2. Expertise coefficient of key factors

Factors affecting the gas industry	First-level expertise index	Second-level expertise index
International sanctions and pressures	89.79	87.08
Investment (financial resources)	80.41	86.66
Technological learning	82.91	85
Export capacity	84.16	80
Exploration level	80.08	84.16
Gas prices	84.16	80.41
gas production capacity	86.66	70.83
Storage capacity	77.08	83.33
Internal consumption	88.33	82.50
Powerful competitors	80	41.80
Specialized human resources	88.33	80
Development and optimization plans	82.50	86.66
Gas infrastructure	84.16	86.25
Supplies and equipment	86.66	75
Research and knowledge bases	70.83	88.75
Government's domestic and foreign policies	86.66	77.08
Demand rate	77.08	86.66
Exchange rate	88.33	75
Regional crisis	80	80

Determine critical uncertainties using the importance index

This indicator shows the importance given by experts to each of the uncertainties in its impact on the gas industry's future. In Table 3, the necessity of each driver constituting the gas industry is calculated. The importance index is calculated as follows:

$$\textbf{Importance index} = \frac{\text{Number of answers to option (high)}*100+\text{Number of answers to option (medium)}*50+\text{Number of answers to option (low)}*25+\text{Number of answers to option (none)}*0}{\text{Total number of answers}} \quad (2)$$

According to the results, "international sanctions and pressures," "development and optimization plans," "technological learning," "export capacity," and "investment (financial resources)" are of the utmost importance.

Table 3. Importance of key factors

Factors affecting the gas industry	First-level importance index	Second-level importance index
International sanctions and pressures	80.79	83.49
Investment (financial resources)	79.41	78.41
Technological learning	81.91	80.91
Export capacity	79.58	78.31
Exploration level	75.39	73.08
Gas prices	61.16	60.41
gas production capacity	77.96	79.66
Storage capacity	78.41	77.08
Internal consumption	62.33	64.50
Powerful competitors	69	41.68
Specialized human resources	62.33	64
Development and optimization plans	80.50	79.45
Gas infrastructure	73.16	72.78
Supplies and equipment	79.66	75
Research and knowledge bases	70.83	73.75
Government’s domestic and foreign policies	66.66	67.08
Demand rate	70.08	68.62
Exchange rate	68.33	69
Regional crisis	65	65.19

Determine critical uncertainties using the consensus index

The Consensus Index indicates the extent to which experts agree on the issue at hand. The closer the consensus index is to zero, the more disagreement there is on that issue. Consensus on which there is no limit; therefore, it can be said that this variable is associated with uncertainty. Table 4 shows the consensus drivers. The consensus index is calculated as follows:

$$\textbf{Consensus index} = \frac{\begin{array}{c}\text{Number of answers to option (a)}*(+2)+\text{Number of answers to option (b)}*(+1)+\\ \text{Number of answers to option (c)}*(-2)+\\ \text{Number of answers to option (d)}*(-1)+\text{Number of answers to option (e)}*(0)\end{array}}{\text{Total number of answers}} \quad (3)$$

According to the results, "international sanctions and pressures," "technological learning," "export capacity," "investment (financial resources)," and "development and optimization plans" have the least consensus among experts, and they are suitable for the development of future scenarios in the gas industry.

Table 4. Consensus index of key factors

Factors affecting the gas industry	First-level consensus index	Second-level consensus index
International sanctions and pressures	0.11	0.09
Investment (financial resources)	-0.14	-0.15
Technological learning	-0.13	-0.11
Export capacity	-0.12	-0.12
Exploration level	-0.29	-0.31
Gas prices	-0.45	-0.46
gas production capacity	-0.19	-0.21
Storage capacity	-0.24	-0.22
Internal consumption	-0.48	-0.44
Powerful competitors	-0.37	0.35
Specialized human resources	-0.47	-0.46
Development and optimization plans	-0.17	-0.14
Gas infrastructure	-0.32	-0.30
Supplies and equipment	-0.25	-0.26
Research and knowledge bases	-0.36	-0.35
Government's domestic and foreign policies	-0.41	-0.39
Demand rate	-0.36	-0.37
Exchange rate	-0.39	-0.34
Regional crisis	-0.41	-0.44

Based on the results obtained from the previous steps, effective drivers from the experts' point of view include "international sanctions and pressures," "technological learning," "export capacity," "investment (financial resources)," and "development and optimization plans." All five key factors have an absolute consensus value below 0.20 (Table 5).

Table 5. Key factors derived from critical uncertainty

Key factors	Total uncertainty (first case)	Total uncertainty (second case)
International sanctions and pressures	1	1
Technological learning	3	2
Investment (financial resources)	4	5
Export capacity	2	3
Development and optimization plans	5	4

Then, using the Fuzzy DEMATEL technique, pairwise comparisons are made between five effective drivers, and the results are shown based on their influence and dependence. Fuzzy DEMATEL is an effective way to analyze the relations between system factors. In DEMATEL, through the analysis of total relations between factors, a better understanding of structural relationships and the ideal way to solve complex system problems can be achieved. Fuzzy DEMATEL is a soft approach to extracting relationships between variables. The higher the influence of a factor, the better it is chosen as a basis for scenario planning. Fuzzy DEMATEL was first introduced at the Geneva Research Center. This method was used to solve complex problems, including famine, energy, environmental protection, etc.

Fuzzy DEMATEL is a multi-criteria decision-making tool based on graph theory that enables us to plan and solve problems. Therefore, we may draw the network relation map (NRM) of several criteria in the cause/effect group to better understand causal relationships. The end product of the Fuzzy DEMATEL process is the presentation of an illustration on which respondents organize their activities and determine the relationship between the criteria. Fuzzy DEMATEL uses surveys to extract the power of direct and indirect causal relations from multiple experts [9]. There are four steps to performing the DEMATEL technique [35]:

Step 1: Formation of direct relation matrix (Z)

When several experts' views are used, the simple average of the views is considered, and a direct relation matrix (Z) is formed.

$$z = \frac{x^1 + x^2 + x^3 + \cdots + x^p}{p} \qquad (4)$$

where p is the number of experts, and x^1, x^2, and x^p represent the pairwise comparison matrix of expert 1, expert 2, and expert p, respectively.

Step 2: Normalize the direct relation matrix

$$N = k * M \qquad (5)$$

where k is the result of the following expression. First, the sum of all rows and columns is calculated, and then, the inverse of the largest number of rows and columns K is formed.

Step 3: Compute the total relation matrix

$$T = N * \langle I - N \rangle^{-1} \qquad (6)$$

Step 4: Draw a causal diagram

In this step, using the sum of row entries (D) and column entries (R) for each factor, the degree of dependence and influence of each factor was obtained; so that the horizontal vector (D + R) shows the influence and dependence of that factor in the system. In other words, the higher the D + R of a factor, the more it interacts with other system factors. The vertical vector (D-R) also shows the influence of each factor. In general, if D-R is positive, it is a causal variable, and if D-R is negative, it is considered an effect.

Tables of direct relation matrix, normalized and total relation are presented in fuzzy form. These tables are not presented in the article due to the limitation of pages in the publication. The fuzzy numbers for these linguistic terms are given in Table 6.

Table 6. The fuzzy linguistic scale

Linguistic terms	Triangular fuzzy numbers
No influence (No)	(0.00, 0.00, 0.25)
Very low influence (VL)	(0.00, 0.25, 0.50)
Low influence (L)	(0.25, 0.50, 0.75)
High influence (H)	(0.50, 0.75, 1.00)
Very high influence (VH)	(0.75, 1.00, 1.00)

The three indicators of influence, dependence, and interaction are obtained from the total effects matrix. The more the key factor or driver interacts, the better it is for scenario planning because it has more influence and dependence. Table 7 shows defuzzified degree of influence and the final ranking of each key factor. Center of area method is used for defuzzificarion of fuzzy data which is shown below:

$$DF_{ij} = \frac{[(u_{ij} - l_{ij}) + (m_{ij} - l_{ij})]}{3} + l_{ij} \tag{7}$$

Table 7. Defuzzified Degree of influence and the final ranking of each key factor

Key factors	Influence	Dependence	Interaction	Final rank
International sanctions and pressures	2.813	2.771	5.115	1
Technological learning	1.285	2.465	4.268	2
Investment (financial resources)	2.157	1.655	4.197	3
Export capacity	1.149	1.047	1.822	5
Development and optimization plans	0.672	1.353	2.934	4

Based on the results of the critical uncertainty technique and Fuzzy DEMATEL, "international sanctions and pressures" and "technological learning" should be used for scenario planning. Because these two variables have the most influence among the variables. Figure 2 presents the four future scenarios of the gas industry based on these two indicators.

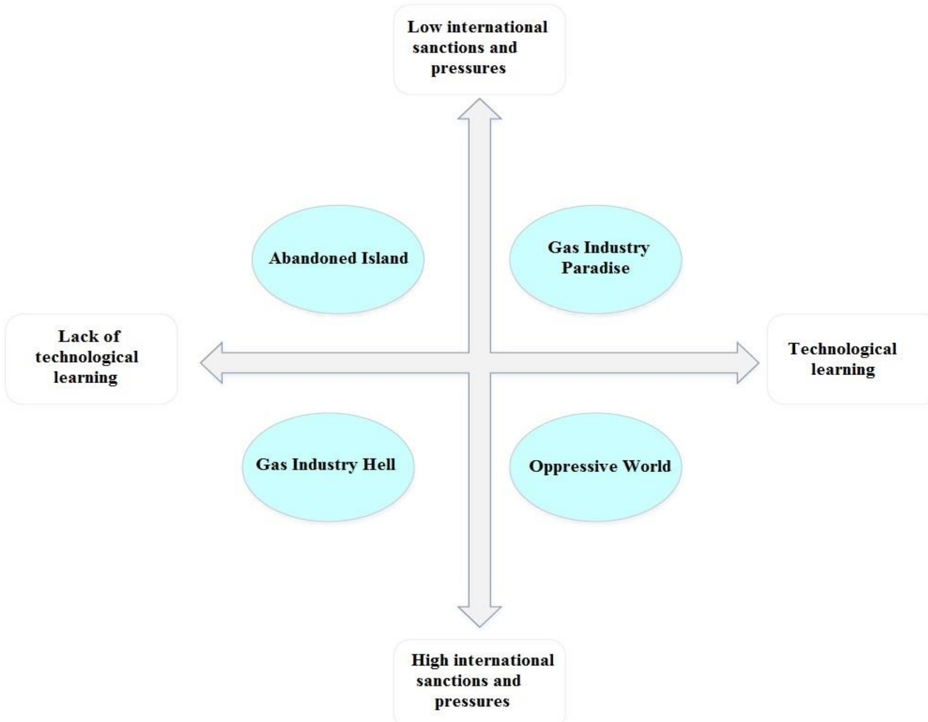

Figure 2. Plausible scenarios for the Iranian gas industry

Development of plausible scenarios for the Iranian gas industry

Given the two key factors of international sanctions and pressures and technological learning, the four scenarios facing Iran's gas industry include "Gas Industry Paradise," "Oppressive World," "Abandoned Island," and "Gas Industry Hell."

- **Gas Industry Paradise**

"Gas Industry Paradise" scenario is the result of a combination of "technological learning" and "low international sanctions and pressures," which shows the most optimum situation for the gas industry in the future. This scenario is somewhat impossible given the situation in the country. In such a situation, the technology and external environment will help the industry's long-term plans. The lifting of sanctions will be an opportunity for the gas industry to use it to increase exports, attract investment, provide technology resources, and procure advanced equipment. Despite the opportunities in the gas industry, planners and managers plan for the future, taking into account past conditions and changes. Managers and planners strive to take advantage of the openings that occur quickly and promptly to empower the industry in the future further. They seek to increase the gas production's volume quickly, sell products to various countries with modern marketing methods, import the necessary technologies and equipment rapidly, work with different foreign companies and countries to manage and develop the industry, and most importantly, invest heavily in R&D. Speed is a key factor in this scenario. Loss of time in the short term can have catastrophic consequences for the industry, so key players must seize the opportunity in the short term to transfer sensitive and essential equipment and technologies.

- **Abandoned Island**

The "Abandoned Island" scenario is the result of a combination of "lack of technological learning" and "low international sanctions and pressures." In this scenario, international sanctions and pressures will be reduced, and the reduction of sanctions will play a crucial role in technology transfer. Transferring modern technologies and cooperation with leading international companies while increasing gas production volume will enhance the efficiency and productivity of gas transmission machines and equipment, improve the quality, and diversify its products. Likewise, due to the improvement of relationships with foreign companies, the IT infrastructure is improved, and the access to international experts is increased. The major problem in the future is the lack of planning for future shocks and threats. The main logic of this scenario is the ability to return and react to the previous situation. In this scenario, due to the lack of long-term and operational plans in R&D, equipment, and technology, once the sanctions return, the gas industry will face numerous problems in technology. The consequence of this scenario is the fragility of the gas industry in the face of external shocks and the lack of sustainable technological progress in the gas industry.

The Iranian gas industry has a weak knowledge base that is rooted in its formation and development process. In the Iranian gas industry, compared to Korea, there is no trace of family businesses. Despite the engineering faculties in the fields of oil and chemistry, however, the training of educated personnel is not appropriate and focused on the interests and issues of the Iranian gas industry. Poor communication with companies and countries with technology has also made technology transfer very difficult. Although the transfer of forces is done qualitatively, its administrative steps and processes are time-consuming. Combining these factors has led to a weak industrial knowledge base in many sectors and does not provide a basis for technological learning. In technological learning, most domestic companies operating in the Iranian gas industry have failed because the available market volume and competitors' comparison with the maximum power of these firms show that they cannot easily bring their production scale to the optimal economic level. It is because these firms cannot access foreign markets. Even in some areas, domestic manufacturers cannot sell their technology or product to Iranian customers. Of course, this issue has a long and deep-rooted history in the oil and gas industry. What is argued to justify it is that Iranian technology producers and developers have no reference. Therefore, in areas where there is a risk, Iranian buyers are unwilling to purchase local equipment or technical knowledge. In this industry, economies of scale in the transmission and distribution sectors were so attractive to domestic companies that they were pushed into this direction of the market. Iran has adopted a strategy of transporting gas throughout the country, even remote villages, through the pipeline.
Consequently, a major economy has been formed in this area. In contrast, there has been no economy of scale in the refining process because there are not many gas refineries. These few development plans have not been made available to Iranian producers. According to reports, no new refinery development plans are on the agenda of the National Gas Company by the end of 2028. In such circumstances, it is natural that there is no economic incentive and scale to develop technology in a sector such as gas refining processes. Overall, in areas such as transmission and distribution where economies of scale exist, technological learning has also occurred more frequently.

In different parts of the gas industry chain, the country's situation is different regarding access to explicit/implicit learning sources. In some parts of the chain where the knowledge source is explicit, technological learning certainly faces fewer barriers. The equipment sector has more explicit knowledge in the industry chain because learning takes place largely from studying and analyzing existing standards. Even in the face of sanctions, there is access to these international norms and standards. On the other hand, in sectors such as refining, the bulk of technical knowledge is in the hands of some large, well-established international companies that spend large sums of money each year to protect their knowledge and strongly prevent it from leaking out of the organization. Even foreign contracts can be a good source for learning, as the parties must have specialized discussions to determine the limits and dimensions of the contract. However, in situations where this possibility has not been provided so far for various reasons, access to explicit knowledge resources is also severely limited.

- **Oppressive World**

The "Oppressive World" scenario is the result of a combination of "technological learning" and "high international sanctions and pressures." Sanctions of industrialized countries against Iran led to a new dynamism in various industries, including the gas industry. With the start of sanctions and the non-entry of European and American companies, the Iranian companies could enter the gas industry because they were eligible for economies of scale to produce industrial products and access explicit knowledge sources. Due to their economies of scale, these companies had a good incentive to acquire technological capabilities. At the same time, due to access to explicit knowledge sources, they could rely on these resources to upgrade their technological capabilities and find the appropriate absorptive capacity and knowledge base to attract more knowledge from foreign partners. However, this is not the case everywhere in the gas industry, and this mechanism has not been activated. Only centers in the gas industry have experienced advancement where active companies have had the motivation and opportunity to enhance their absorptive capacity. For example, in equipment manufacturing, the level of technological capabilities is significantly higher than other sectors because both the scale of industry needs are cost-effective and attractive in this area, and Iranian industrialists have access to basic knowledge and engineering.

- **Gas Industry Hell**

"Gas Industry Hell" scenario is the result of a combination of "lack of technological learning" and "high international sanctions and pressure." In this scenario, international sanctions and pressures are increased. At the same time, due to the lack of a technological learning plan, the industry will be increasingly exposed to the crisis. Under such circumstances, growing sanctions will eliminate the possibility of government investment in the industry's infrastructure, and funding for many projects will be suspended. On the other hand, many foreign companies and investors will be reluctant to continue working with Iranian parties. Many domestic experts may even leave the country due to the devaluation of the national currency and the poor state of payments. Lack of strategic planning for crises by domestic stakeholders will cause the gas industry to face several problems in production and distribution. In this scenario, the industry's long-standing habit to foreign parties to advance the industry and unilateral dependence on foreign partners will have catastrophic consequences for the industry as sanctions increase. The main features of this scenario include reduction of gas production in the medium-term, decreased export capacity, backwardness in gas projects compared to competitors, stopping of many gas projects, lack of access to modern knowledge and technology, and low efficiency of human resources and equipment in this industry. In this scenario, the escalation of sanctions will further exacerbate the weaknesses of the gas industry and problems such as outdated technology, migration of industry elites, non-cooperation of foreign partners, and staffing problems along with unpreparedness and fragility of the industry may even cause the gas industry to collapse.

Select the most plausible scenario

In this section, the MOORA method was used to select the most likely scenario. The MOORA was first used as a multi-criteria optimization technique by Brauers and Zavadskas due to the lack of weighting method and the possibility of providing non-psychological assessments. This method has been proposed to overcome weight problems in previous optimization models such as PROMETHEE, TOPSIS, AHP, and ELECTRE due to its features, including simplicity, low volume and time of mathematical calculations, and high stability [19]. Therefore, a questionnaire was provided to the experts, and they were asked to comment on each scenario in terms of three criteria: (1) compliance with current trends, (2) consistency with current statistics and data, and (3) fact-based plausibility. Questionnaires were then collected, experts' opinions were aggregated using the geometric mean method, and finally, the results led to the ranking of scenarios.

The steps to implement the MOORA method are [30]:

Step 1: Formation of decision matrix: A decision matrix is a matrix in which the columns are the criteria and the rows are the options, and each cell is the score of each option in terms of each criterion. This method is used only for ranking options and is not used for weighting and ranking criteria.

Step 2: Decision matrix normalization: The normalization of the decision matrix is done softly (Table 8).

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \quad (8)$$

Table 8. Normalized matrix

Scenario	Compliance with trends	Consistency with current data	Fact-based plausibility
Gas Industry Paradise	0.26	0.34	0.29
Abandoned Island	0.34	0.34	0.36
Oppressive World	0.43	0.42	0.58
Gas Industry Hell	0.78	0.76	0.65

Step 3: Evaluation of the positive and negative effects: For optimization, the normalized performance is added in case of maximization (for beneficial criteria) and subtracted in case of minimization (for non-beneficial criteria). Ranking means yielding, y_i, which is calculated according to the following equation:

$$y_i^{*} = \sum_{j=1}^{g} w_j \; x_{ij}^{*} - \sum_{j=g+1}^{n} w_j \; x_{ij}^{*} \qquad (j=1,2,\ldots,n) \quad (9)$$

Table 9. Ranking of gas industry scenarios

Scenario	y_i	Final rank
Gas Industry Paradise	0.28	4
Abandoned Island	0.35	3
Oppressive World	0.70	1
Gas Industry Hell	0.52	2

According to the results, the scenarios "Oppressive World," "Gas Industry Hell," and "Abandoned Island" are in the first, second, and third ranks, respectively. According to the three indicators, "Oppressive World" is the most plausible scenario. "Gas Industry Hell" is the worst-case scenario, and "Gas Industry Paradise" is the best-case scenario. According to experts, the "Oppressive World" scenario is more likely to be realized (see Table 9).

5. Conclusion

The present study sought to identify plausible and probable future scenarios for the gas industry. Therefore, key factors were extracted through literature review and interviews with gas industry experts. Then the final factors were selected using the binomial test, critical uncertainty technique, and Fuzzy DEMATEL. Finally, the most plausible scenario was selected through the Fuzzy MOORA method. Based on the key factors of "international sanctions and pressures" and "technological learning," four scenarios were identified: "Gas Industry Paradise," "Oppressive World," "Abandoned Island," and "Gas Industry Hell." The "Abandoned Island" scenario shows that international sanctions and pressures are easing thanks to improved international relations. However, due to a lack of foresight and long-term planning for technology learning, the industry may face serious problems at any time.

The "Gas Industry Hell" scenario represents a limited and isolated industry in which foreign sanctions are intensified. The lack of technological learning will lead to a more pronounced effect of intensified sanctions. The escalation of sanctions will lead to the deficiency of financial resources for implementing projects, lack of investment by foreign companies, the departure of specialized human resources, and disruption of the gas industry.

On the other hand, due to the lack of technological learning in the gas industry and heavy dependence on foreign countries, the effects of foreign sanctions will be severe and catastrophic. Dealing with the forthcoming sanctions requires a special plan to govern the country in the face of sanctions. Part of this program is special rules and regulations for governing the country in emergencies caused by the impact of economic sanctions. This issue, as a shortcoming, threatens the organizational system, and in practice, prevents executive managers from risk-taking, which is necessary for the management of the country in such an era. Enacting emergency regulations requires public determination among governing bodies that can help lawyers and experts deal with the consequences of economic sanctions.

On the other hand, the gas industry is technology-intensive and important for the Iranian economy. Despite numerous domestic and foreign investments in this industry, the technological dependence on foreign countries has not decreased much in the last four decades in several sectors. In other words, little technological learning has taken place in the industry. However, policies and planning must be done at different levels to achieve this goal. At the macro level, the government body should provide special facilities and supporting channels for selected competitive industries to improve their technology learning and technological capabilities. Therefore, it is very likely that the gas industry, which has one of the largest gas reserves in the world, will be one of the selected industries with high priority. Until this decision is made at the macro level, one cannot expect anything special to happen, and the situation will continue as it is now. The second necessity at the macro level is to formulate a catch-up strategy and industrial development in selected industries. This strategy has dimensions beyond technology in terms of content, but the development of technological capabilities will certainly be one of its main modules.

One of the main consequences of this strategy is to identify the main aspects and orientations of the industry in the field of learning. After that, learning reinforcement mechanisms can be developed at a micro and operational level under those strategies and orientations. This scenario shows the most pessimistic situation in the future. In the "Oppressive World" scenario, despite the intensification of foreign sanctions and unfavorable economic conditions, the effects of sanctions will be less felt due to plans to promote technological learning in the gas industry and the country's economy.

The gas industry’s plans for the future include networking policies, policies to develop and strengthen the knowledge base, incentive policies for companies and economic institutions, cooperation with multiple partners instead of dependence on limited parties, investment in R&D, reliance on internal capabilities, strengthening the private sector, working closely with universities and research centers, and consolidating technical and applied training to provide specialized workforce.

The "Gas Industry Paradise" is the most optimistic scenario and somehow the ideal future of the gas industry. In this scenario, sanctions are relieved, and it is possible to finance and cooperate with international companies.

In the future, while developing technological learning, efforts will be made to import the necessary technologies and equipment as soon as possible and increase gas production and its products to reduce the possibility of re-sanctions. On the other hand, by involving more parties and partners and making them economically dependent on the Iranian gas industry, other countries' costs of re-sanctions can be increased. After plausible scenario planning, it is time to choose a possible scenario. From the experts' perspective, "Oppressive World" was chosen as the most probable scenario. Suggestions for research are presented as follows:

1) The future research of investment in other industries.
2) Conducting research considering other financial and economic variables in this industry.
3) Conducting research with other future research approaches and methods in the gas industry and comparative comparison with those researches.

Considering the desired scenarios in research and probability of their occurrence, implications of the research will be provided in Policy Making Level.

- Supporting the development of critical proposals
- Emphasizing the organizational problems in the topics of the fields
- Holding co-thinking workshops and scenarios among opinion-makers of different approaches
- Developing and running communities on new approaches
- Holding different conventions and conferences
- Adding variety to the topic of the discipline

Finally, the limitations of the research include the following:

1) Future research projects are usually long and time consuming, and due to the wide range of topics in this research, more time was needed, which due to time constraints, created problems for the researcher. For this reason, one of the most important obstacles of this research is the number of research stages and the time required to perform each of the research stages.
2) One of the other limitations of this research is the lack of an excellent reference and detailed documentation.
3) To formulate strategies, the method of interviewing with focus groups has been used, which according to the diamond model is based solely on creativity and other dimensions such as interaction and evidence are weak in them.
4) It takes time to learn about fuzzy multi-criteria decision making techniques and it is difficult to access specialized people in the field of software used in research.

Conflict of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Aggestam, F., & Wolfslehner, B. (2018). Deconstructing a complex future: Scenario development and implications for the forest-based sector. *Forest Policy and Economics*, 94, 21-26.
2. Ahmadi, E., Maleki, M., Sanavi Fard, R., Fathi, M.R. (2020). Future Study of Supply Chain in Oil Industry with Scenario Planning Approach. *Journal of Iran Future Studies*, 5(1), 81-104.
3. Alipour, M., Hafezi, R., Amer, M., & Akhavan, A. N. (2017). A new hybrid fuzzy cognitive map-based scenario planning approach for Iran's oil production pathways in the post-sanction period. *Energy*, 135, 851-864.
4. Atef, M., Salimi, A., and Azadmanesh, H. (2012). *Evaluation of Strategic Plans in the Development of Iran Gas Industry*, 2nd Conference and Exhibition of Industrial Energy Management, Tehran.
5. Azgoli, M., and Pourjabari, P. (2016). An Introduction to the Appropriate Methodology of Futures Studies: A Defense Approach, *Quarterly Journal of Defense Management and Research*, Defense Faculty and Research Institute, 15 (81), 134-111. (In Persian)
6. Azizkhani, Z., Esmaeelpour, R. (2014). The Impact of the Futures Studies Macro-Trends on the Functioning of Iranian Public Libraries, *Future Studies,* 9, 267.
7. Batrouni, M., Bertaux, A., & Nicolle, C. (2018). Scenario analysis, from BigData to black swan. *Computer Science Review*, 28, 131-139.
8. Chambers, I., Costanza, R., Zingus, L., Cork, S., Hernandez, M., Sofiullah, A., & Kubiszewski, I. (2019). A public opinion survey of four future scenarios for Australia in 2050. *Futures*, 107, 119-132.
9. Du, Y. W., & Zhou, W. (2019). New improved DEMATEL method based on both subjective experience and objective data. *Engineering Applications of Artificial Intelligence*, 83, 57-71.
10. Fathi, M. R., Maleki, M. H., Sobhani, S. M., & Koksal, C. D. (2020). Future study of operations research-based on scenario planning and soft systems methodology, *Foresight*, 22(2), 223-249.

11. Fathi, M.R., Maleki, M.H., KOKSAL, C., Yuzbaşıoğlu, N., Ahmadi, V. (2019). Future Study of Spiritual Tourism based on Cross Impact Matrix and Soft Systems Methodology. *International journal of Tourism & Spirituality*, 3(2), 19-41.
12. Fathi, M. R., Razi moheb saraj, S., Nasrollahi, M., & Maleki, M. H. (2021). Future Study of Livestock Industry in Khorasan Razavi Province using the Critical Uncertainty Approach and the DEMATEL-MOORA Technique. *Journal of Animal Environment*, 13(4), 69-82.
13. Fathi, M.R, Maleki, M.H., Moghaddam, H. (2018). Futures investment and financing of rail transportation industry (machinery and equipment). *Future Study Management*, 29(113), 33-54.
14. Fathi, M. R., Khaheshi, F., Pahlevanzadeh, M., & Tizroo, A. (2022). Scenario Planning for the Future of Religious Tourism in Mashhad City in 1404 Horizon. *Journal of Tourism and Development*, 11(4), 85-98.
15. Fathi, M., Zeinali, M., Torabi, M., & Alavizdeh, S. (2022). Structural analysis of the future of Iranian online banking employing a MICMAC approach. *Technological Forecasting and Social Change*, 183, 121943.
16. Fathi, M.R., Sobhani, S.M., Maleki, M.H. and Jandaghi, G. (2021). Future study of textile industry in Iran using the MICMAC and soft operational research methods, *Foresight*, 23(4), 439-456.
17. Fathi, M.R., Torabi, M. and Razi Moheb Saraj, S. (2022). The future of apitourism in Iran based on critical uncertainty approach and DEMATEL/COPRAS techniques., *Journal of Tourism Futures*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JTF-09-2021-0215
18. Fergnani, A. (2019). Mapping futures studies scholarship from 1968 to present: A bibliometric review of thematic clusters, research trends, and research gaps. *Futures*, 105, 104-123.
19. Ghoushchi, S. J., Yousefi, S., & Khazaeili, M. (2019). An extended FMEA approach based on the Z-MOORA and fuzzy BWM for prioritization of failures. *Applied Soft Computing*, 81, 105505.
20. Jamali, A., Faghih, A., Fathi, M. R., & Rostami, F. (2023). A Combined Fuzzy Multi-Criteria Decision Making Framework for Evaluation of Islamic Banks: A Case of MENA Region. *Fuzzy Optimization and Modeling Journal*, 4(2), 49-65.
21. Jandaghi, G., Fathi, M. R., Maleki, M. H., Faraji, O., & Yüzbaşıoğlu, N. (2020). Identification of Tourism Scenarios in Turkey Based on Futures Study Approach. *Almatourism - Journal of Tourism, Culture and Territorial Development*, 10(20), 47-68.
22. Jandaghi, G., Fathi, M. R., maleki, M. H., & soleymani sarvestani, M. H. (2022). Future Studies of Sustainable Development of Iranian Machine Carpet Industry Using MIC-MAC and SSM. *Journal of Environmental Science and Technology*, 24(2), 153-167.
23. Kashanipour, M., Fathi, M.R., Faraji, O., Rahmani, M. (2021). Sustainability Reporting Future Study Using Scenario Planning Approach, *Iranian journal of Value & Behavioral Accounting*, 5(10). 69-101.
24. Maleki, M.H., Khasehi Varnamkhasti, V., Fathi, M.R., Saffarinia, M. (2019). Future Studies of Religious Tourism of Qom Province based on Scenario Planning Approach. *Journal of Tourism and Development*, 8(3), 184-205.
25. Mottaghi, M. (2019). Futures of Iran’s oil and gas; scenarios by 2035. *Petroleum Business Review*, 3(4), 63-86.
26. Naqdibak, B., and Keramati, M.A. (2013). Future scenarios for downstream projects in Iran's oil, gas and petrochemical industries, 2nd National Conference on Futures Studies, Tehran.
27. Nilforoushan, H., Ghaffarzadegan, M., Peymankhah, S., & Rahmani, S. (2017). Technological Learning Failure Causes in Gas Industry, *Journal of Science & Technology Policy*, 9(4), 31-44.
28. Petroleum, B. (2015). BP statistical review of world energy. British Petroleum, London.
29. Rahimi, G. (2007). Iran Gas Industry: Current Situation and Prospects, *Political and Economic Information*, 242.
30. Sahu, A. K., Mahapatra, S. S., Chatterjee, S., & Thomas, J. (2018). Optimization of surface roughness by MOORA method in EDM by electrode prepared via selective laser sintering process. *Materials Today: Proceedings*, 5(9), 19019-19026.
31. Samadi, A., Emami Meybodi, M. (2015). Investigating the Impact of Unconventional Gas Resources on Iranian Natural Gas Production: A System Dynamics Approach. *Iranian Journal of Energy Economics*, 4 (15), 13-53.
32. Samadi, A.H., Eydizadeh, S. (2014). Designing a Dynamic Model for Iran Gas Industry: A System Dynamics Approach, *Journal of Economic Modeling Research*, 4 (14), 151-181.
33. Soleymani Sarvestani, M., Jandaghi, G., Fathi, M.R., Maleki, M.H. (2019). Future Studies of Iran Handmade Carpet Industry Using Critical Uncertainty Approach. *Journal of Iran Future Studies*, 4(1), 141-169.
34. Servati, Y., Ghodsypour, S. H., & Soleimani, M. (2016). Application of Advanced Impact Analysis in Developing Iran's Gas Industry Scenarios. *Industrial Engineering and Management Systems*, 15(4), 307-317.
35. Shakerian, M., Choobineh, A., Jahangiri, M., Alimohammadlou, M., Nami, M. (2019). Introducing a New Model for Individual Cognitive Factors Influencing Human Error Based on DEMATEL Approach. *Iranian Journal of Ergonomics*, 6 (4), 66-74.
36. Shamaei, A., Naseri, S., Nazemi Ashni, A., and Alizadeh, A. (2010). robustness of gas industry development plans and strategies using futures studies." National Conference on Iranian Technology Management, Iran Technology Management Association, Pardis Technology Park, Allameh Tabatabai University, Aerospace Industries Organization, 4.
37. Shahbazi, A. (2012). Iranian oil and gas industry prospect in the horizon of 2025: do's and don'ts. International Conference on Oil, Gas, Petrochemical, and Power Plant, 1.
38. Schwartz, P. (1996). The art of the long view: paths to strategic insight for yourself and your company. Currency.
39. Spaniol, M. J., & Rowland, N. J. (2019). Defining scenario. *Futures & Foresight Science*, 1(1), e3.
40. Tari, F., Roteh, S.A., Sadat, S. (2017). Resistance economy in the gas industry, *Economic Journal* (Bimonthly Review of Economic Issues and Policies), 17 (11), 5-24.
41. Trevithick, S., Flabouris, A., Tall, G., & Webber, C. F. (2003). International EMS systems: New South Wales, Australia. Resuscitation, 59(2), 165-170.
42. Van der Hoeven, M. (2013). World energy outlook 2012. International Energy Agency: Tokyo, Japan.

Fathi, M. R., Khosravi, A., Razi Moheb Saraj, S., & Behrooz, A. (2023). Futures Studies of Gas Industry in Iran based on Fuzzy MCDM Methods and Critical Uncertainty Approach. *Fuzzy Optimization and Modeling Journal*, 4(3), 72-91.

https://doi.org/10.30495/fomj.2023.1990204.1101

Received: 30 June 2023 Revised: 18 November Accepted: 19 November