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Designing an efficient multi-objective mathematical model to choose the best strategy for critical investment risks in oil and gas projects

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Abstract
According to the conducted research, oil and gas industry projects have many complexities and uncertainties, and investment in these projects is associated with high risks. In this research, while identifying the most critical risks that have an impact on investing in oil and gas projects, they have been identified in the first place. Then, the importance of each of the specified criteria is determined. To achieve the aforementioned goals, modern computing methods have been used. In the phase of identifying factors from fuzzy Delphi; In the importance and prioritization stage, multi-criteria decision-making methods are used, and in the allocation stage, multi-objective mathematical modeling is used. Therefore, first, a list of 21 investment risks in industry and gas was collected by reviewing the literature and research backgrounds. The collected risks were refined and finalized using the fuzzy Delphi approach. Finally, the risks of sanctions by an institution or country, liquidity, health risks (such as the corona epidemic), financial potential, exchange rate fluctuations, and sudden changes in inflation as risks. considered in this research. Then, considering factors such as quality, cost, technology, time, and information preparation as indicators influencing the occurrence of considered risks, their importance has been determined using the best-worst method. According to the weight calculated for each of these factors, respectively equal to 0.23; 0.09; 0.52; 0.07, and 0.09 are estimated. Then, according to the importance obtained by using the GRA-VIKOR approach, the risk ranking was determined by considering the factors affecting them. Finally, by using the three-objective linear programming model with the objectives of maximizing the level of quality, minimizing cost and time, and solving it using the epsilon-constraint method, an appropriate response strategy is determined for each of the considered investment risks.
Keywords: Investment risk, fuzzy Delphi, fuzzy GRA-VIKOR, augmented epsilon constraint method

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1-Introduction

Every day, organizations are looking for ways to increase productivity and minimize costs and increase profits based on their organizational strategy (Burrr, 2016). In a general definition, productivity is the logical relationship between the goods produced and the input required for their production, including cost and energy. In other words, productivity is the effective use of resources such as labor, capital, energy, and information (Forozanfar and Ebrahimzadeh Ghazani, 2016). But in the meantime, one reason that may have caused them a lot of damage and played an important role in increasing the costs of project-oriented organizations is poor project management and the existence of delays as a potential risk during its various stages (Ghasemi et al. 2022; Touti and Chobar, 2020). Unlike task organizations where employees are separated and have mainly independent goals, in project organizations all resources are used to achieve specific goals with a regular and specific arrangement in the form of projects to achieve the outputs determined by management (Sheikh et al. 2019, Olleik et al. 2022). As a result, organizations that produce or present most of their products against the customer's customized design and manage their activities in the form of projects are called project-oriented organizations (Mokhtari Far et al., 2014; Chobar et al. 2022). These organizations put a lot of emphasis on the project and manage most of their activities in the form of projects (Khelghati and Fazeli Kebriya, 2017). If it is possible to identify the factors that cause delays in the completion of projects by creating an organized method and taking effective steps to reduce or eliminate these factors, and on the other hand, allocate resources to them according to strategic priorities, these costs will be greatly reduced. Since project-oriented companies look at projects as a strategic option for planning (Alizadeh et al, 2021; Asgari et al. 2022). Because, choosing the right projects on the one hand and their correct and timely implementation on the other hand is of double importance (Arditi et al., 2017). Based on this, project risk assessment is very important for financial decision-makers because they need to establish a balance between investment risk and expected profit maximization (Junior et al. 2022). In addition, investors and other project stakeholders are interested in past information about the efficiency and effectiveness of resource allocation (Shafipour-omran et al. 2019; Eshghali et al. 2023). Therefore, economic aspects should not be analyzed as the only factor and should also be evaluated in the evaluation of factors such as the behavior of stakeholders and organizational structure (Keshavarz Turk and Nikoyeh, 2015; Hosseini et al. 2022). In addition, corporate social responsibility emphasizes responsibility and accountability as the basis of an organization's behavior in society and oversees how to conduct responsible business along with wealth production (Naghizadeh, 2019; Pourghader chobar et al. 2022). Companies see social responsibility as a business strategy that increases their reputation and credibility. For example, Carroll proposed the social responsibility of each company in four dimensions economic, legal, moral, and voluntary responsibility respectively (Rahmanidoust et al. 2019). Economic responsibility means producing goods and services that society needs and selling them at a fair price. Economic responsibility refers to the fact that the business must be profitable. This responsibility emphasizes that economic responsibility must be carried out within legal limits. The moral responsibility of the company is not bound by legal frameworks. The voluntary responsibility of the company is the voluntary or philanthropic nature of business (Ramezan Nia and Rezaei, 2016). Since most of the projects are implemented in a dynamic and complex environment, uncertainty and risk are among their inherent characteristics. Therefore, reaching predetermined goals in projects, which are usually time, cost, and quality, falls under the radius of these risks (Khodadadi Dehkordi et al., 2015, Chen et al. 2022). Most experts believe that one of the main characteristics of oil and gas industry projects is that these projects are risky (Askari et al., 2016). Oil and gas projects, due to their complexity, risk, and the existence of a large number of stakeholders, must technically be by the budget and accurate schedule and with few errors (Briel et al. 2013, Norouzi, 2021). To ensure the efficiency and accuracy of oil and gas projects, many industrial and academic studies have been conducted to develop project management strategies to reduce project errors. One of the basic issues in the field of oil and gas projects is the identification of risks and their analysis (Sun et al. 2022, Ahmadi and Peivandizadeh, 2022; Bayanati et al., 2022). Risk is a measurable component of uncertainty whose probability of occurrence and size of damage can be estimated and predicted. Risk can be introduced as a deviation from the desired level, which is positive or, in most cases, negative. Therefore, risk analysis is important in selecting projects and group construction works (Dziadosz and Rejment, 2015). Hilson and

Webster in 2012 defined risk as uncertainty that can have a positive or negative effect on one or more objectives. Also, the revision committee of the American Insurance and Risk Association has expressed its view on risk as follows: Risk is the uncertainty of the outcome of an event that has two or more possibilities, and in the discussions of financial theories and investment decisions, risk means the amount of difference. The real return on an investment is the expected return. In general, project risks are the result of the uncertainty that exists in all projects and their components. The size of project parameters such as time, cost, and quality according to expectations in a project can be mentioned as an example of uncertainties in projects.

Despite the importance of oil and gas projects, these projects still fail. During the studies conducted on 365 oil and gas projects, it was determined that a large number of these projects failed in terms of schedules and budgets (Eygm, 2014). According to another similar research, 78% of oil and gas projects experience time delays and cost increases (Merrow, 2012). On the other hand, in the long term, the level of complexity and risk has increased in all sectors of this industry. Most of the world's oil and gas fields have already been discovered. Of course, large sectors are still active in the exploration of new resources, but the main focus of oil and gas industry research centers is currently on new extraction methods, such as gas processing and horizontal drilling, as well as the development of smaller sectors. In addition, the increase in the ratio of global oil reserves was concentrated only for a few countries, which are some of the members of OPEC, and this means an increase in the influence of those countries in the global equations.

In recent years, due to the increasing number of startup contracting companies with low financial and human capital, these companies enter into tenders that offer prices without considering the market risk (due to limited organizational capital) and during the operation period. The issue of the contract is due to various reasons that can be rooted in the project elements, which cause the project to be prolonged and impose a lot of costs on the employer and the contractor. And the events are beyond the control of the contractor and employer. Delays in the completion of projects due to the lack of negligence of the contractor (permissible delays) and the imposition of costs due to the extension of the project, part of which costs are directed to the contractor, and finding the main causes of loss and damage and finding a solution to reduce it through the resolution of contractual issues and amend laws and directives. But in many cases, there are problems between the owner and the contractor, such as whether the contractor has the right to demand additional costs in the above-mentioned case or not. Such situations usually involve questioning the facts, causative factors, and interpretation of the contract.

The purpose of this research is to provide an approach to quantitatively and qualitatively manage the risks of oil and gas projects through the use of multi-criteria decision-making methods under a fuzzy environment and mathematical programming. This approach consists of two steps. In the first stage, the risks related to each of the projects and the importance of each of them are identified using MCDM techniques. In the second stage, a mathematical planning model is presented to select projects according to the objective of profit maximization and risk minimization. Also, response strategies to each risk are specified.

Based on the things mentioned above, before defining the goals and choosing the approaches for future study, to implement the goals, we will conduct a comprehensive and systematic study. Due to the wide importance of the oil and gas field, many researchers paid attention to this field and it has been considered from different aspects. Investment is one of these aspects that was seen many times in the surveys. Although several studies have investigated this issue, a study that comprehensively examines the identification of investment risks in the oil and gas industry and determines the most critical risks in this field by applying such a different approach at the same time and also identifies strategies does not appear simultaneously for critical risks. Therefore, this research has many innovations in terms of method, which from the modeling aspect of this research, taking into account the three goals of cost-quality-time, deals with the approach of choosing the best response to risk in terms of optimization to decide with what quality and cost and at what time. Respond to the desired risk and choose the optimal strategy. Also, to identify risks, this research has another innovation, which has been calculated with the GRA-VIKOR method and has prioritized them, but in general, the innovation of the model is as follows:

• Risk identification and risk communication by GRA-VIKOR method,
• Considering the appropriate strategy to respond to risks according to the objectives of time, cost, and quality,
• Considering risk factors through gray theory as a component of uncertainty that can be measured.
But in terms of method, this research has innovation as follows:
• Providing a multi-stage integrated decision-making method that can determine the most important risks in the first stage. Then, determine their final weights and finally prioritize them according to criticality. Also, assign the best strategy for each risk.
• Explain a general pattern to determine the appropriate response to deal with each risk identified in the investment for oil and gas projects.
In the second part, the conducted research and the theoretical foundations related to the research topic are discussed. The methods and processes carried out to carry out the research are detailed in the third section. In the fourth part, the findings and achievements obtained from the implementation of the project are comprehensively described. Finally, the managerial insights, obtained results, final summary, and suggestions for future research works are stated in the fifth and sixth section.

2- Literature review and research background

By studying the articles published in reliable scientific journals for the term risk, we came across various and numerous definitions that had almost a single meaning and concept. Webster's culture has defined risk as exposure to risk. In general, risk means unexpected fluctuations leading to losses. Unexpected property means unpredictability because predictable negative volatility is interpreted as cost, not risk. The dictionary of investment terms also considers risk as the potential loss of investment that can be calculated (Saadat Joy Ordkolu and Ali Rahimi, 2013). Risk in the world means risking and taking risks, and in financial terms, it is expected return fluctuations. Risk is a prediction deviation that can be positive or negative. A positive deviation is defined as a favorable risk and a negative deviation is defined as an unfavorable risk. In other words, all systematic and unsystematic risks that lead to an increase in the stock price and profitability of a company are called favorable risks, and all avoidable and unavoidable risks that hurt the stock value of a company are called unfavorable risks.

2-1- Risks in oil and gas projects

Chen and Linn (2017) provide evidence that changes in oil and natural gas field investment measured by drilling rigs positively respond to changes in future oil and natural gas prices, consistent with predictions based on value maximization behavior. These results hold for regions of the world that are dominated by private independent oil companies rather than national oil companies. Theophilus et al. (2017) believe that the oil and gas industry is facing catastrophic events, most of which are attributed to organizational and operational human factor errors. In addition, they showed that failure in national and international industry regulatory standards automatically creates preconditions for incidents to occur. Bergh et al. (2017) collected quantitative and qualitative risk data in the oil and gas company to manage psycho-social risk and discover specific and common psycho-social risks in the oil industry. Ghandi and Lawell (2017) analyzed the rate of return and risk factors of Shell International Exploration Company in the post-sale service contract in Iran.

Tan et al. (2018) proposed a new method to create a risk matrix to assess safety risks in the oil and gas industry. Risk frequency and outcome are two desirable criteria in the process of creating a risk matrix. More than two criteria and several experts are often involved in this, so a multi-criteria and multi-person information integration model (MEMCII) is built into this paper. In the first stage, the method of determining experts' weights is introduced to integrate experts' evaluation scores based on objective weights and subjective weights. In the second step, the regularized weighting operator (WOWA) with a utility interpolation function is proposed to get the overall result of integrating people's risk attitudes. Finally, a risk matrix is created to show which risks are very dangerous and which risks can be ignored.

Kim and Choi (2019) investigated the causal effect of future price risk on the debt-to-equity ratio of oil and gas project companies. Also, the difference in such an effect between upstream and downstream industries was investigated, because upstream projects are more exposed to price risk than downstream projects. Finally, significant differences in risk probability were observed between upstream and downstream projects.

In their study, Iwegbue et al. (2020) investigated the concentration of 28 polychlorinated biphenyl compounds, including 12 dioxane PCBs and 7 indicators PCBs, in the sediments around oil production facilities in the Syracuse River Basin of the Niger Delta in Nigeria. The aim was to describe the spatial patterns, sources, and ecosystem risks associated with exposure to PCBs in the sediments of this river basin.

Akhtaruzzaman et al. (2020) study oil price risk in financial and non-financial industries around the world during the COVID-19 pandemic. The experimental results obtained showed that oil-supplying industries generally benefit from positive shocks to oil price risk, while oil-consuming industries and financial industries react negatively to positive oil price shocks. The outbreak of COVID-19 seems to moderate the exposure to oil price risk in financial and non-financial industries. This issue also creates important implications for energy risk management during the pandemic.

Vora et al. (2021) proposed an environmental risk framework to provide improvement solutions in the oil industry. This framework is based on a review of environmental risk assessment guidelines. This review also presents potentially relevant Environmental/Ecological Risk Assessment (ERA) guidelines and, based on this review, initially proposes an ERA framework for understanding the environmental impacts of EOR (Enhanced Oil Recovery) solutions.

Gorlenko and Murzin (2021) developed an integrated method for occupational risk assessment for oil and gas production companies. In this work, among the available methods, four methods were selected that take into account a significant number of risk-generating aspects, namely: the method of assessing the level of individual occupational risk, the Fine-Kinney method, and the scoring method. Occupational hazards and the method of sociological investigation of workers. According to the results of applying the integrated assessment of job risks, most of the positions had a "medium" risk level, but for jobs that were engaged in manual work and had a lower degree of work automation, a "high" risk level was determined.

Khalilzadeh et al. (2021) presented a new approach of failure mode and effects analysis (FMEA) based on fuzzy multi-criteria decision-making methods (MCDM) and multi-objective planning model for risk assessment in the planning phase of oil and gas projects in Iran. This research includes several steps. First, 19 Health and Safety Executive (HSE) potential risks in (Oil and Gas Construction Projects) OGCP were classified into six categories by the Delphi method. Then, using the fuzzy SWARA method, the authors calculated the weight of major HSE risks, and FMEA and PROMETHEE approaches were used to identify the priority of the main risk factors. Finally, a binary multi objective linear programming approach was developed to select risk response strategies and an augmented electronic constraint method (AECM) was used. Considering the well-known triple project constraints of time, cost, and quality, which organizations usually face, OGCP HSE risks were identified and prioritized. Also, appropriate risk response strategies were suggested to the managers to be adopted according to the situation.

2-2- Uncertainty in oil and gas projects

Schiozer and Ligero (2004) in their article, refer to the fact that the analysis of decisions related to oil field development is very risky due to the presence of uncertainty in the process, due to the weakness of quantitative methodologies of the effects of these uncertainties and due to the existence of the high number of variables that must be considered. Suslick et al. (2009) referred to the progress made in recent decades regarding the analysis of risk and uncertainty related to oil production and exploration, reviewed the main new aspects, and the progress made in the production and exploration phase.

Zhang and Wang (2011) presented a system dynamics model to analyze and predict the scale and structure of upstream investment for an oil company based on real results from the performance of an oil company in China. This model was used to analyze the investment effect of a large oil company in China, and the results showed that the total scale of upstream investment will slowly decrease in a short period. In their research, Cao et al. (2016) discussed geological control factors on oil distribution in a combined manner. Geochemical methods, including Soxhlet extraction, are used to evaluate the quantitative capacity of oil. In this research, microscopic observations, Soxhlet extraction, analysis by Rock-Eval method, evaluation of Total organic carbon (TOC), analysis of reservoir rock characteristics, and analysis of pore structure were used to investigate geological control factors in oil reservoirs. Based on the above explanations, it was concluded that hydrocarbon production capacity plays an important role in reservoir rocks with suitable porosity and fine pore bottlenecks in the oil industry.

In his research, Cerra (2017) examined two cases: First, a decrease in oil income can cause a sharp increase in inflation by reducing foreign exchange for imports and increasing the fiscal deficit that is financed by money growth. Second, when the foreign currency is justified, the devaluation of the official exchange rate can reduce the fiscal deficit and subsidies for the purchase of foreign currency and cause a temporary reduction in inflation. In their research, Tang et al. (2018) analyzed the investment opportunity of an oil project in the development and production stage, considering the uncertainty, irreversibility, and flexibility of management.

Brown et al. (2020) investigated the responsiveness of non-renewable resource companies to production taxes using data from the oil sector in the United States. In this research, the effect of cutting taxes on oil drilling was also examined from an economic point of view. They find that the response to a one-dollar tax increase per unit of output is at least eight times greater than the effect of an equivalent decrease in output price.

Naifar et al. (2020) investigate the dynamic and non-linear impact of oil price returns on sovereign Credit Default Swaps (CDS) that extend to the oil-rich countries of the Gulf Cooperation Council and other major oil exporting countries, namely Venezuela, Mexico, and Russia. they paid. The empirical results showed that there is no small effect on the sovereign credit risk of Saudi Arabia, the United Arab Emirates, and Norway, which have the most important sovereign wealth funds in the world.

Alfalih and Hadj (2020) showed that human capital has a positive conditional effect on the effects of foreign direct investment on long-term employment in the oil industry. While the role of law and order in the relationship between employment and foreign direct investment is negative. The results show that oil leasing can only increase employment in the near term, while its long-term effect on job creation is negative.

Esmaeili and Kashani (2022) identified and classified the root causes (i.e., early precursors) of cost overruns in oil and gas construction projects. This study used content analysis to identify 38 frequent cost overrun factors and 11 root causes in oil and gas construction projects. The Delphi method was used to confirm this classification. The findings of this study help oil and gas professionals in reducing the risk of cost overruns in oil and gas projects and achieving budget goals.

Rawat et al. (2022) proposed solutions for better development of the City Gas Distribution (CGD) sector in India by focusing on identifying business risks that cause delays in oil and gas projects and suggesting appropriate mitigation strategies. A comprehensive literature review was conducted following a seven-step model to provide a comprehensive list of risk classifications and factors, risk identification methods, and strategies to reduce risks. The weighted average ranking method was used to identify the top ten risks affecting oil and gas projects. The research identifies ten main risks that often affect oil and gas projects, which are: project cost, poor project management, changing economic parameters, exchange rates, government regulations and laws, contractor and subcontractor issues, shortages of Skilled labor, delays in approvals, health and safety issues and force majeure. In addition, this study recommends the implementation of joint risk management to prevent CGD project delays.

Rahayu and Wulandari (2022), in this study, the fuzzy Delphi method is used to obtain expert agreement on the definition of elements and features in the electronic portfolio process, especially in the issuance of competency certificates. Fuzzy Delphi helps identify and prioritize internal and external factors that can be used to develop the design of e-portfolio systems. The results of empirical studies show a list of factors that can be used to build an electronic portfolio model and support the certification process. The results of this study contribute to the needs of researchers and developers in understanding the decision-making process of factors and features of Indonesia's e-portfolio model for competency certification.

Considering the conducted research, some of which were briefly mentioned, oil and gas industry projects have many complexities and uncertainties. Therefore, investing in these projects is associated with high risk. Although the use of risk assessment and management methods and techniques has become very common due to hardware and software developments, previous research has not yet been able to provide a comprehensive view of risks in oil and gas, especially in the investment sector. Considering the importance of this industry from the economic aspect and the necessity of mass investments in this part of the country, it is important to identify and prioritize investment risks in a methodical and structured way. According to this research gap, the current research deals with collecting and identifying investment risks in the first step. In the next step, these identified risks are ranked using strong approaches. And in the last step, to reduce the effects of risks, appropriate response strategies are considered for each risk. Considering the mentioned steps, it can be said that the articles that have considered all the three mentioned steps have not been noticed and in this sense, the current research is a pioneer. Therefore, the most important research gaps are:

• Failure to include uncertainty as a risk in oil and gas project investment studies,

• Failure to pay attention to adopting a suitable strategy to properly respond to investment risks in oil and gas projects.

• Failure to pay attention to a comprehensive approach to prioritizing investment risks.

So, providing a multi-stage integrated decision-making method that can determine the most important risks in the first stage is the main contribution of this paper. Besides explaining a general pattern to determine the appropriate response to deal with each risk identified in the investment for oil and gas projects is another contribution of this paper.

3- Research method

Research is a methodical study, so it is essential to know the appropriate research methods. The current research, which is in the field of obtaining information about investment risks in oil and gas companies, is practical in terms of its purpose. The data required in this study were extracted through a researcher-made questionnaire. To collect primary information, library methods (reading articles, books, printed interviews, research papers, booklets of scientific conferences, and printed texts indexed in databases, and the Internet) have been used. Also, to collect field data, the necessary information has been compiled with a suitable questionnaire design. In connection with the used questionnaires, for each of the selected approaches, a questionnaire was designed according to that approach and to the criteria considered by the researcher of the current research. It should be mentioned that due to the lack of personal access to all experts, communication with them, sending and receiving questionnaires was done through virtual networks and telephone. The sampling method in this research is available to design. To collect information, the opinions of experts in the field of oil and gas are used.

The current study can be described from the point of view of data collection as follows. In this research, three documentaries, Delphi, and survey methods have been used to collect information. This information has been done with the cooperation of oil and gas sector experts. To collect the necessary information for the theoretical foundations of the research and to form a conceptual model, the documentary and library method and the review of the latest scientific articles and books related to the risks of the oil and gas industry projects have been used by referring to the reliable scientific websites. Then, to refine and finalize the risks in oil and gas projects, the fuzzy Delphi technique has been used to design the presented conceptual model in line with the consensus of the experts' point of view. Also, the survey method has been used to implement the designed model in the organization in question. According to the extracted factors and determined criteria, questionnaires were prepared and sent to the experts of the oil and gas company, and the experts rated the factors according to the criteria and chose the appropriate risk response strategy.

The research community is the managers and engineers of the oil and gas exploitation company. Also, academic experts have been used to achieve theoretical saturation. Also, to understand the hidden points in the collected data and the characteristics of some members of the research community, based on work history, education, and age, it is depicted in table 1.

Table 1. Details of participants

Row	Age			Education			History			Organizational position
	25 to 30	30 to 35	35 to 40	Bachelor	Master	Ph.D	5>	10>	15>	
Expert 1			*	*				*		Managing Director
Expert 2			*		*		*			The financial manager of the company
Expert 3		*		*					*	The operations manager (oil field) of the company
Expert 4			*			*		*		Executive Director (Oil Field) of the company
Expert 5			*	*					*	Executive director (gas field) of the company
Expert 6		*		*			*			Director of Information Technology (Oil Field) of the company
Expert 7		*			*			*		Company sales manager
Expert 8			*	*				*		Marketing manager of the company
Expert 9		*			*				*	Information technology manager (gas field) of the company
Expert 10			*		*				*	The operations manager (gas field) of the company

The theoretical framework of the present research is shown in figure (1) to understand more about the stages of the study.

Fig. 1. Research steps

In this research, to analyze the fuzzy Delphi methods for screening and identifying the risks of oil industry projects, the best-worst method is used to determine the weights of risk assessment indicators and the GRA-VIKOR combined technique to determine critical risks in conditions of information uncertainty. To solve multi-criteria decision-making methods and the GRA-VIKOR combined approach, Excel software is used, and GAMS software is used to solve BWM and multi-objective mathematical programming models.

3-1- Mathematical Modeling: Planning strategy allocation to critical risks

In the current research, the focus is on identifying investment risks in oil and gas projects. To minimize these risks, taking into account the opinion of experts in the oil and gas sector, strategies to respond to each of the risks have been identified. To choose the most appropriate response strategy to each of the critical risks, a zero and one linear planning model with three objectives is proposed. Among the six identified critical risks that were mentioned earlier and considering the opinions of experts in this field, criteria such as quality, cost, and time were considered as the goals of the current research model. It can be said that quality is the most important factor in any operational work, so the first goal considered is to maximize the quality level of strategies. Since the implementation of the response strategy is associated with spending money, therefore, cost minimization is considered the second objective of the model. Finally, considering the nature of the company's operations and the importance of the time spent on implementing strategies, minimizing the time needed to implement response strategies is the last goal of the current research.

Before presenting the model, it is necessary to mention that the following assumptions are considered in this model:

- Critical risks have been identified and are limited in number.
- Risk response strategies were identified by considering experts' opinions and are limited in number.
- The quality level of each strategy is clear.
- Time-related information is available.
- The data related to the cost of work operations is clear.

Considering the mentioned explanations and assumptions, the desired model is presented as follows:

3-1-1- Symbols

A) Sets

I The set of critical risks $i = \{1,2,3, \dots, m\}$

J The set of response strategies $j = \{1,2,3, \dots n\}$

B) Parameters

Q_{ij} The quality level of the *i*th critical risk to respond to the *j*th strategy
T_{ij} The time required for the *i*th critical risk to respond to the *j*th strategy
E_{ij} The cost required for the *i*th critical risk to respond to the *j*th strategy
TP_i The maximum number of strategies allowed to be assigned to each critical risk

C) Decision variables (binary)

x_{1j} If the *j*th strategy is chosen for liquidity risk, it is one, otherwise it is zero.

y_{2j} If the *j*th strategy is chosen for the risk caused by exchange rate fluctuations, it is one, otherwise, it is zero.

z_{3j} If the *j*th strategy is chosen for the risk of sanctions by an institution or country, it is one, otherwise, it is zero.

P_{4j} If the *j*th strategy is chosen for the health risk (such as the corona epidemic), it is one, and otherwise, it is zero.

O_{5j} If the *j*th strategy is chosen for the risk caused by sudden changes in inflation, it is one, otherwise, it is zero.

M_{6j} If the *j*th strategy is selected for potential financial risk, it is one, otherwise, it is zero.

$$max f_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} Q_{ij}(X_{ij} + Y_{ij} + Z_{ij} + P_{ij} + O_{ij} + M_{ij}) \quad (1)$$

$$min f_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}(X_{ij} + Y_{ij} + Z_{ij} + P_{ij} + O_{ij} + M_{ij}) \quad (2)$$

$$min f_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}(X_{ij} + Y_{ij} + Z_{ij} + P_{ij} + O_{ij} + M_{ij}) \quad (3)$$

$$\text{St.} \sum_{j=1}^{n} X_{ij} \le TP_i \qquad \forall i \quad (4)$$

$$\sum_{j=1}^{n} X_{ij} \ge 1 \qquad \forall i \quad (5)$$

$$X_{ij}.Y_{ij}.Z_{ij}.P_{ij}.O_{ij}.M_{ij} \in \{0.1\} \quad \forall i.j \quad (6)$$

In this model, the objective functions (1), (2), and (3) respectively, maximize the quality of resources, minimize the time required to implement the response strategy, and the last relationship minimizes the cost spent. Constraints (4) show the maximum number of methods assigned to each critical risk. Constraint (5) guarantees that at least one response strategy is given to each risk. Finally, the limit (6) is the non-functional limit of the model, which takes the value of 1 if it is a response to the *i*th critical risk of the *j*th strategy, and is equal to zero otherwise.

4- Numerical results

In this research, the employees of the oil and gas company are the statistical population of the current research, and a number of these employees were randomly selected as a statistical sample. In this research, the risks of an investment in oil and gas projects were first identified by literature review. Then, to refine the identified risks, 41 experts were selected from the employees of the oil and gas company. The experts considered in this research are distributed based on age, education, and work experience.

4-1- Crediting the risks with the fuzzy Delphi approach and extracting the final risks

This section aims to credit the identified risks. As mentioned earlier, a list of potential risks related to investment in oil and gas projects was prepared by studying the literature review and research background. After collecting investment risks in oil and gas projects to refine and screen the risks, a prepared questionnaire was given to a group of experts in the field of oil and gas and we were asked to identify the most effective factors. For this purpose, the following steps were taken:

- Preparing a list of investment risks in oil and gas companies by studying the literature review and research background.
- Interviews with 41 experts in the field of oil and gas. They were asked to agree or disagree with each of the identified risks.
- Considering the opinions of experts, the risks were identified and the final risks were identified and refined using the fuzzy Delphi validation method.

In this context, we first consider the identified risks. Then, taking into account the results obtained from the fuzzy Delphi method to achieve an easier comparison, the prioritization of risks is presented in the format of figure (2).

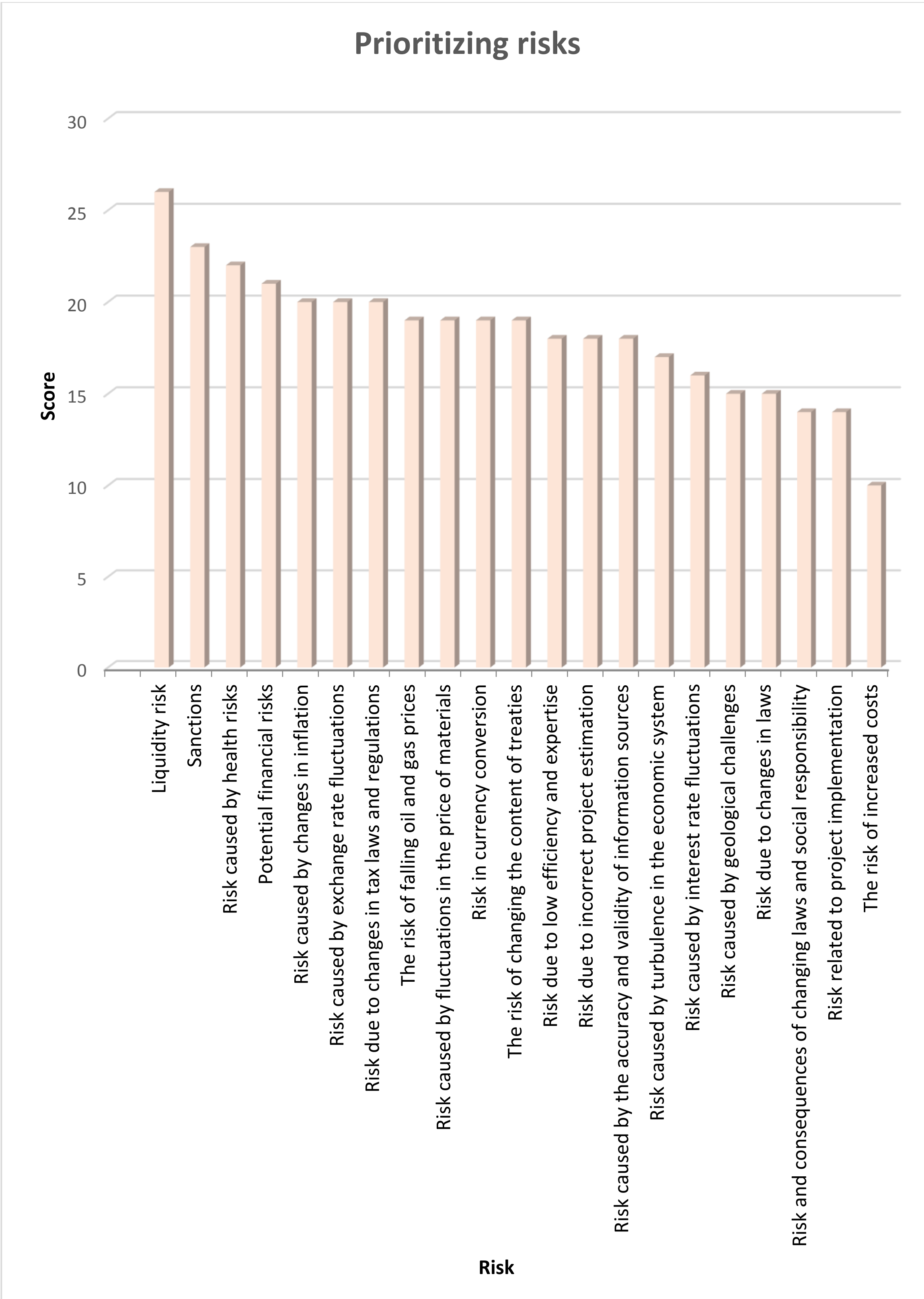

Fig. 2. Prioritizing risks

Considering the opinions of experts and applying the fuzzy Delphi validation approach, the potential risks in the field of investment in oil and gas projects are described in table (2).

Table 2. Critical risks based on the fuzzy Delphi approach

Code of risks	Risks
R_1	Liquidity risk
R_2	The risk of sanctions by an institution or country
R_3	Risk caused by health risks (such as the corona epidemic)
R_4	Potential financial risks
R_5	Risk caused by sudden changes in inflation
R_6	Risk caused by exchange rate fluctuations

4-2- Determining the weights of risk assessment criteria using the best-worst approach

To determine the critical risks using the fuzzy GRA-VIKOR approach, we need criteria. In this regard, by reviewing the literature and research conducted in this field, criteria such as quality, cost, technology, time, and information preparation were considered as criteria for evaluating the identified risks. Now, in this section, we will determine the weight and importance of each of the mentioned criteria. For this purpose, the BWM approach, which is one of the multi-criteria decision-making methods, is considered. The steps used in this section are as follows:

• Preparing a questionnaire to determine the most important (best) and least important (worst) criteria to be used in the BWM method.

• Since in this approach, the decision-makers determine the criteria, therefore the prepared questionnaire is distributed among 7 oil and gas industry experts.

• Collecting questionnaires, and sorting the obtained answers.

It should be noted that in this approach, the best criterion is the most desirable or the most important criterion, and the worst criterion is the least important of them. According to the explanations mentioned, the best and worst criteria specified by experts in the oil and gas field can be seen in table (3).

Table 3. Best and worst metrics identified by experts

Row	Criterion	The most important criterion	The least important criterion
1	Quality	5-6	-
2	Cost	-	3
3	Technology	1-4-7	-
4	Time	-	2-5-6
5	Providing information	2-3	1-4-7

Considering the steps defined for the best and worst method, at this stage, priorities should be determined to determine the best criterion among all the identified criteria. In other words, in this section, we are trying to determine the values. Therefore, pairwise comparisons are made between the best criteria and other criteria. For this purpose, first considering the questionnaire prepared for the BWM method, the experts are asked to prioritize the best criterion chosen by them over other criteria. Before presenting the obtained results, it should be noted that if more than one criterion is selected as the best criterion according to the experts, the best criterion is chosen on an optional basis.

Table 4. The final weights of the criteria

No	Criterion	W_i	*Weight values*
1	Quality	*W1*	*0.23*
2	Cost	*W2*	*0.09*
3	Technology	*W3*	*0.52*
4	Time	*W4*	*0.07*
5	Providing information	*W5*	*0.09*

According to the table (4), it is clear that the criteria of technology and quality respectively have the highest weight among the above 5 criteria.

4-3- Identification of critical risks

The purpose of the current research is to identify investment risks in the oil and gas industry. In this context, 21 risks were identified by reviewing the literature and research background. To evaluate the identified risks, 5 criteria of quality, cost, technology, time, and information preparation were introduced. In the previous sections, the identified risks were refined and finalized by considering the experts' opinions, and finally by using the fuzzy Delphi approach and taking into account the opinions of the experts of the oil and gas company, 6 risks such as liquidity risk, sanctions, health, financial, Inflation and exchange rate were considered as final risks. Now, in this section, determining the critical risks among the 6 final risks is the goal. For this purpose, the fuzzy GRA-VIKOR approach is used, which is explained in detail in the following sections.

4-4- Identification of critical risks - Fuzzy GRA-VIKOR approach

In this subsection, the fuzzy GRA-VIKOR approach is used to determine the critical risks among the refined risks with the fuzzy Delphi approach and consider the weights obtained for the criteria.
At this stage, linguistic variables are used to evaluate and rank options and consider criteria, which are triangular fuzzy numbers in table (5) (Ebrahimi and Bridjalal, 2020; Jahangiri et al. 2021).

Table 5. Verbal variables

very unimportant	*unimportant*	*medium*	*Important*	*very important*
(0,0.1,0.3)	(0.1,0.3,0.5)	(0.3, 0.5, 0.7)	(0.5,0.7,0.9)	(0.7, 0.9,1)

The aggregate matrix of balanced decision-making can be seen in the table (6).

Table 6. Aggregation matrix of weighted decision criteria

Criterion / Risks	Quality			Cost			Technology			Time			Providing information		
Liquidity	12.5	23.9	41.7	6.8	18.5	33.1	14.3	30.3	49.1	3.1	10.1	22.9	7.2	18.2	30.8
Sanctions	11.7	25.7	40.3	9	18.9	37.9	7.7	20.1	36.5	3.5	12.1	26.9	15.1	27.3	36.2
Health field	19.7	28.7	43.1	10.4	23.9	37.9	16.1	32.5	47.7	4.3	11.5	23.3	12.5	24.1	37.2
Financial potential	9.1	26.7	41.7	4.6	12.1	24.9	17.3	35.2	48.8	4.9	14.1	26.7	7.7	19.5	31
swelling	11.7	24.7	38.9	8.8	20.3	30.7	16.6	29	45	4.3	11.1	21.9	15.3	27.7	36.6
exchange rate	15.9	27.7	43.1	12.6	27.7	40.5	13.8	27.7	40.6	2.7	7.3	18.1	9.5	19.9	32.2

Then the considered fuzzy decision matrix is normalized in the form of a table (7).

Table 7. Unnormalized fuzzy decision matrix

Criterion / Risks	Quality			Cost			Technology			Time			Providing information		
Liquidity	0.09	0.28	0.68	0.07	0.07	0.07	0.15	0.43	0.9	0	0.03	0.04	0.14	0.44	0.83
Sanctions	0.08	0.3	0.65	0.05	0.07	0.06	0.08	0.29	0.67	0	0.02	0.03	0.28	0.66	0.97
Health field	0.14	0.33	0.7	0.04	0.06	0.06	0.16	0.46	0.87	0	0.02	0.03	0.24	0.58	1
Financial potential	0.06	0.31	0.68	0.10	0.11	0.09	0.18	0.5	0.89	0	0.02	0.03	0.14	0.47	0.83
swelling	0.08	0.29	0.63	0.05	0.07	0.07	0.17	0.41	0.82	0	0.02	0.04	0.29	0.67	0.98
exchange rate	0.11	0.32	0.7	0.04	0.05	0.06	0.14	0.39	0.47	0	0.04	0.04	0.18	0.48	0.87
max	0.14	0.33	0.7	0.1	0.11	0.09	0.18	0.5	0.9	0	0.04	0.04	0.29	0.67	1
min	0.06	0.28	0.63	0.04	0.05	0.06	0.08	0.29	0.67	0	0.02	0.03	0.14	0.44	0.83

In the following, by using the triangular fuzzy numbers of table (7), it becomes the definite numbers of the table (8).

Table 8. Normalized fuzzy decision matrix

Criterion / Risks	Quality	Cost	Technology	Time	Providing information
Liquidity	0.33	0.07	0.47	0.025	0.46
Sanctions	0.33	0.06	0.33	0.017	0.64
Health field	0.37	0.055	0.48	0.017	0.6
Financial potential	0.34	0.1	0.51	0.017	0.47
swelling	0.32	0.065	0.45	0.02	0.65
exchange rate	0.36	0.05	0.34	0.03	0.5
max	0.37	0.1	0.52	0.03	0.45
min	0.31	0.05	0.33	0.017	0.46

The coefficients of the weighted fuzzy gray relation (GRA) are calculated by considering the positive and negative ideal solution as the reference sequence. In this first step, the specified phase distance $d(\tilde{A}.\tilde{B})$ should be calculated. These coefficients can be seen in the table (9).

Table 9. Fuzzy distance matrix

Criterion / Risks	Quality	Cost	Technology	Time	Providing information	Quality	Cost	Technology	Time	Providing information
	+	+	+	+	+	-	-	-	-	-
Liquidity	0.05	0.03	0.04	0.01	0.20	0.02	0.02	0.15	0.01	0
Sanctions	0.04	0.04	0.19	0.01	0.01	0.02	0.02	0	0	0.18
Health field	0.00	0.05	0.03	0.01	0.06	0.06	0.01	0.16	0	0.14
Financial potential	0.04	0.00	0.00	0.01	0.18	0.03	0.06	0.19	0	0.02
swelling	0.05	0.04	0.06	0.01	0.00	0.01	0.02	0.13	0	0.19
exchange rate	0.01	0.06	0.10	0.00	0.16	0.05	0.00	0.08	0.01	0.04

Considering the fuzzy distance matrix, we enter the step of calculating the coefficients of the weighted fuzzy gray relation, which was calculated in the form of a table (10).

Table 10. Weighted fuzzy gray coefficients matrix

Criterion / Risks	Quality	Cost	Technology	Time	Providing information	Quality	Cost	Technology	Time	Providing information
	+	+	+	+	+	-	-	-	-	-
Liquidity	0.32	0.34	0.33	0.39	0.21	0.36	0.35	0.22	0.39	0.4
Sanctions	0.33	0.33	0.20	0.38	0.4	0.36	0.37	0.4	0.4	0.2
Health field	0.4	0.21	0.35	0.34	0.31	0.3	0.38	0.22	0.39	0.23
Financial potential	0.33	0.4	0.4	0.37	0.21	0.35	0.31	0.2	0.4	0.36
swelling	0.22	0.25	0.30	0.35	0.41	0.4	0.37	0.24	0.39	0.2
exchange rate	0.37	0.29	0.26	0.40	0.22	0.25	0.4	0.28	0.35	0.33

After calculating the coefficients of the weighted fuzzy gray relation, the values of $\tilde{S}_i$ and $\tilde{R}_i$are calculated. Then the values of $\widetilde{\boldsymbol{Q}}_{\boldsymbol{i}}$ were calculated according to tables (11) and (12).

Table 11. The values obtained for Si and Ri

	S_i	R_i
Liquidity	1.60	0.39
Sanctions	1.63	0.40
Health field	1.61	0.40
Financial potential	1.71	0.40
swelling	1.54	0.41
exchange rate	1.54	0.40
max	1.71	0.41
min	1.54	0.40

Table 12. Qi values

Risks	$\widetilde{\boldsymbol{Q}}_{\boldsymbol{i}}$
Liquidity	1.13
Sanctions	0.73
Health field	0.64
Financial potential	0.36
swelling	0.50
exchange rate	0.84

At this stage, the options should be ranked and the most suitable answer should be chosen. For this purpose, according to relation (7), the DQ index is calculated as follows:

$$DQ = \frac{1}{(6-1)} = 0.2$$

$$Q_2 - Q_1 = 0.5 - 0.36 = 0.14 < DQ = 0.2$$

$Q_3 - Q_1 = 0.64 - 0.36 = 0.28 > 0.2$

Therefore, following the completion of the fuzzy GRA-VIKOR approach, the options "potential financial risk" and "risk caused by sudden changes in inflation" were recognized as the most critical risks. It should be noted that this approach identifies the best option(s) but is not able to decide on other options.

4-5- Strategies to respond to risks

Assigning response strategies to identified critical risks is the last stage of the current research. For this purpose, the three-objective model, which was proposed to respond to risks in the third section, has been solved using the evolved epsilon-constraint method. As mentioned earlier, in this research, a list of critical risks was first identified by reviewing the literature. By using the fuzzy Delphi validation method, the identified risks were refined and finalized. To evaluate the refined risks, evaluation criteria were identified and their weights were determined through the BWM approach. In the next step, critical risks must be identified, for this purpose, the fuzzy GRA-VIKOR approach was used and critical risks were identified. Since two approaches were considered to identify critical risks and different answers were obtained for each approach. Therefore, in consultation with experts, the optimal solutions obtained were considered critical risks.

Finally, for each of the identified critical risks, several response strategies were found, for this purpose, research was conducted with several experts in the oil and gas industry regarding strategies for responding to the risks, and finally, the desired strategies were collected. Since several strategies have been defined for each risk, after consultation with experts, critical risks have finally been identified and several appropriate response strategies and model decision variables are presented in table (13). It should be noted that the strategies considered in table (13) were identified following the studies of research works and the consensus of informed experts in the field of the oil and gas industry.

Table 13. Response strategies to critical risks

Row	*Risk*	*Response strategies*
1	*Risk caused by sudden changes in inflation*	Considering the amount of foreign currency and riyals together in contracts The definition of allowance in severe inflation conditions Payment of the difference to the contractor in case of severe inflation Proper timing of projects Controlling fluctuations in the price of raw materials Monitoring and controlling economic indicators in the business environment, welfare and income distribution
2	*Potential financial risks*	Integrated resource management system Definition of FRM financial resources risk management Get low interest loans Creating institutional capacities at the company level and creating opportunity capital Providing part of the financial resources needed to implement projects in the country as a substitute or complement to domestic resources Timely completion of projects
3	*Liquidity risk*	Creating a stable portfolio Development of cash flow management system Development of interdisciplinary performance audit system Risk sharing with the employer Use of expert forces for cost management Portfolio development
4	*Risk caused by health risks (such as the corona epidemic)*	Insurance for employees Staff training Control of primary health factors Proper nutrition of employees Use of specialist safety officers Use of appropriate and standard safety-sanitary equipment
5	*The risk of sanctions by an institution or country*	Increasing the quality of domestic production Supporting domestic producers Granting loans and financial support for domestic production Creating facilities to convert the currency of the country into valid currencies Changes in the provisions of contracts by the government Increasing production capacity in common fields
6	*Risk caused by exchange rate fluctuations*	Exchange rate stability strategy and acceptance by the employer Cash flow management Definition of currency amount in contracts Using balance sheet hedging (to cover exchange rate fluctuations) Potentially significant savings in bank fees Designing foreign exchange swap contracts

Source: research findings (collected according to the opinions of oil industry experts with an exploratory perspective)

4-5-1-model input parameters

To solve the stated mathematical model, we need to define the input parameters for the goals mentioned in the model such as quality level, time, and cost. Since it is not possible to access all the input information, therefore, in this research, after consultation with the experts, it was agreed that the data collected in the fuzzy Delphi questionnaire should be used as the parameters of the model. Since the Delphi approach used in this research is in a fuzzy environment and the collected numbers are triangular fuzzy numbers, therefore, by using the appropriate defuzzification method, the fuzzy numbers are first converted into definite numbers, and then these definite numbers are entered into the model. Math was used.

Based on the above explanations, the required parameters of the first model are expressed in the form of fuzzy triangular numbers. As mentioned, during the process of collecting response strategies for identified critical risks, since the use of a response strategy to each risk incurs costs for the company and considering the budget limit defined by each company in its organizational chart, Every company is not able to adopt all defined strategies for every critical risk. Therefore, in this model, an upper limit for the number of response strategies considered for each bet is considered, which can be seen in table (8).

4-5-2- The results obtained from solving the model

GAMS software is used to solve the available model. For this purpose, the model was solved 11 times per grid point related to the problem (qi) according to the table (14). The obtained Pareto solutions are presented by solving the model in the table (15). Considering the table (15) and consulting with experts, among the 11 Pareto points, point 9 was selected as the best point. At this point, the values obtained for the objective functions of quality level, time, and cost are respectively f1=48, f2=42, and f3=22. Considering Pareto point 9, how to allocate strategies to each of the risks is according in table (16). In this section, the Pareto fronts obtained from the objective functions of the model are shown in figures (2) to (4):

Table 14. Input parameters in the form of fuzzy triangular numbers

	$max f_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} Q_{ij}(X_{ij}+Y_{ij}+Z_{ij}+P_{ij}+O_{ij}+M_{ij})$	$min f_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}(X_{ij}+Y_{ij}+Z_{ij}+P_{ij}+O_{ij}+M_{ij})$	$min f_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} E_{ij}(X_{ij}+Y_{ij}+Z_{ij}+P_{ij}+O_{ij}+M_{ij})$
X_{11}	(3,5,7)	(5,7,9)	(1,3,5)
X_{12}	(3,5,7)	(5,7,9)	(7,9,9)
X_{13}	(3,5,7)	(7,9,9)	(5,7,9)
X_{14}	(5,7,9)	(5,7,9)	(7,9,9)
X_{15}	(5,7,9)	(3,5,7)	(1,1,3)
X_{16}	(5,7,9)	(1,3,5)	(1,3,5)
Y_{21}	(7,9,9)	(3,5,9)	(3,5,7)
Y_{22}	(1,3,5)	(1,3,5)	(5,7,9)
Y_{23}	(5,7,9)	(1,3,5)	(5,7,9)
Y_{24}	(5,7,9)	(5,7,9)	(5,7,9)
Y_{25}	(5,7,9)	(1,3,5)	(7,9,9)
Y_{26}	(5,7,9)	(1,3,5)	(5,7,9)
Z_{31}	(5,7,9)	(5,7,9)	(3,5,7)
Z_{32}	(7,9,9)	(1,3,5)	(1,3,5)
Z_{33}	(5,7,9)	(7,9,9)	(7,9,9)
Z_{34}	(5,7,9)	(7,9,9)	(5,7,9)
Z_{35}	(7,9,9)	(5,7,9)	(1,3,5)
Z_{36}	(7,9,9)	(7,9,9)	(5,7,9)
P_{41}	(1,3,5)	(7,9,9)	(7,9,9)
P_{42}	(3,5,7)	(3,5,7)	(3,5,7)
P_{43}	(7,9,9)	(7,9,9)	(7,9,9)
P_{44}	(5,7,9)	(7,9,9)	(7,9,9)
P_{45}	(1,3,5)	(3,5,7)	(5,7,9)
P_{46}	(3,5,7)	(3,5,7)	(5,7,9)
Q_{51}	(3,5,7)	(5,7,9)	(1,1,3)
Q_{52}	(1,1,3)	(1,1,3)	(1,3,5)
Q_{53}	(7,9,9)	(5,7,9)	(7,9,9)
Q_{54}	(7,9,9)	(7,9,9)	(7,9,9)
Q_{55}	(7,9,9)	(5,7,9)	(3,5,7)
Q_{56}	(3,5,7)	(7,9,9)	(5,7,9)
M_{61}	(1,1,3)	(1,1,3)	(1,1,3)
M_{62}	(5,7,9)	(1,3,5)	(1,1,3)
M_{63}	(7,9,9)	(7,9,9)	(5,7,9)
M_{64}	(5,7,9)	(7,9,9)	(5,7,9)
M_{65}	(5,7,9)	(3,5,7)	(1,3,5)
M_{66}	(5,7,9)	(7,9,9)	(5,7,9)

$$\tilde{A} = (l.m.u) = \frac{l+2m+u}{4} \quad (8)$$

Table 15. The input parameters are unphased

Critical Risks	Variables	**X11**	**X12**	**X13**	**X14**	**X15**	**X16**
R_1	$\boldsymbol{Q_{ij}}$	5	5	5	7	7	7
	$\boldsymbol{T_{ij}}$	7	7	8.5	7	5	3
	$\boldsymbol{E_{ij}}$	3	8.5	7	8.5	1.5	5
R_2	**Variables**	**Y21**	**Y22**	**Y23**	**Y24**	**Y25**	**Y26**
	$\boldsymbol{Q_{ij}}$	8.5	3	7	7	7	7
	$\boldsymbol{T_{ij}}$	5	3	3	7	3	3
	$\boldsymbol{E_{ij}}$	5	7	7	7	8.5	7
R_3	**Variables**	**Z31**	**Z32**	**Z33**	**Z34**	**Z35**	**Z36**
	$\boldsymbol{Q_{ij}}$	7	7	7	7	7	7
	$\boldsymbol{T_{ij}}$	7	3	8.5	8.5	7	8.5
	$\boldsymbol{E_{ij}}$	5	3	8.5	7	3	7
R_4	**Variables**	**P41**	**P42**	**P43**	**P44**	**P45**	**P46**
	$\boldsymbol{Q_{ij}}$	3	5	8.5	7	3	5
	$\boldsymbol{T_{ij}}$	8.5	5	8.5	8.5	5	5
	$\boldsymbol{E_{ij}}$	8.5	5	8.5	8.5	7	7
R_5	**Variables**	**Q51**	**Q52**	**Q53**	**Q54**	**Q55**	**Q56**
	$\boldsymbol{Q_{ij}}$	5	1.5	8.5	8.5	8.5	5
	$\boldsymbol{T_{ij}}$	7	3	7	8.5	7	8.5
	$\boldsymbol{E_{ij}}$	1.5	3	8.5	8.5	5	7
R_6	**Variables**	**M61**	**M62**	**M63**	**M64**	**M65**	**M66**
	$\boldsymbol{Q_{ij}}$	1.5	7	8.5	7	7	7
	$\boldsymbol{T_{ij}}$	3	3	8.5	8.5	5	8.5
	$\boldsymbol{E_{ij}}$	1.5	1.5	7	7	3	7

Table 16. Values obtained for epsilon

				K										
				0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Objectives	$\boldsymbol{f_i^{max}}$	$\boldsymbol{f_i^{min}}$	**Rang**	**Epsilon ($\boldsymbol{\varepsilon_i}$)**										
Objective-1	224	19.5	204.5	224	203.55	183.1	162.65	142.2	121.75	101.3	80.85	60.4	39.95	19.5
Objective-2	223	21	202	223	202.8	182.6	162.4	142.2	122	101.8	81.6	61.4	41.2	21
Objective-3	213.5	16	197.5	213.5	193.75	174	154.25	134.5	114.75	95	75.25	55.5	35.75	16

By solving the model, the obtained Pareto solutions are shown in table (17). Also, the maximum, minimum, and average values obtained for the Pareto solutions are listed in the table (18).

Table 17. Pareto's answers

ε_i	Objective-1	Objective-2	**Objective-3**
0	224	223	**213.5**
1	204.5	204	**181**
2	184	185.5	**153**
3	163	163	**127.5**
4	142.5	143	**107**
5	123.5	122.5	**86.5**
6	103	102	**66**
7	89.5	82	**50.5**
8	70.5	61.5	**35**
9	**48**	**42**	**22**
10	34.5	25	**16**

Table 18. Maximum, minimum, and average values for Pareto solutions

	Quality level objective function	**Time objective function**	**Cost objective function**
The maximum amount	224	223	213.5
The lowest amount	34/5	25	16
Average values of the objective function	126.09	123.04	96.18

Table 19. Response strategies for critical risks with model solutions

Row	**Risk**	**Response strategy**
1	The risk of sanctions by an institution or country	Supporting domestic producers
2	Liquidity risk	Use of expert forces for cost management
3	Risk caused by health risks (such as the corona epidemic)	Staff training
4	Potential financial risks	Integrated resource management system
5	Risk caused by exchange rate fluctuations	Exchange rate stability strategy and acceptance by the employer
6	Risk caused by sudden changes in inflation	Considering the amount of foreign currency and riyals together in contracts

In connection with a table (19), it can be said that after identifying critical risks for investment in the oil and gas industry with the GRA-VIKOR approach, this research also aims to create response strategies to critical risks. In this regard, by defining the three-objective model and solving the model with the help of the epsilon constraint method, the appropriate strategies to respond to the identified critical risks were determined, and these strategies can be seen in the table (19). These strategies can be used to reduce the negative effects of investment risks in the oil and gas industry, as well as create more reliable investments.

In other words, this helps decision-makers and managers to provide appropriate solutions to reduce the effects of critical risks in addition to making the optimal decision.

Multi-objective optimization methods are used when a balance needs to be established between two or more conflicting objectives to reach optimal decisions in the system. In many cases, the objective functions defined in the multi-objective optimization problem conflict with each other. In such a case, it is said that there are Pareto optimal solutions for a multi-objective optimization problem (theoretically, there may be infinite Pareto optimal solutions for a multi-objective optimization problem). Therefore, in this section, the Pareto fronts obtained from the objective functions of the model are shown in figures (2) to (4). A Pareto chart is a chart to show and categorizes information to find out which causes have the most role in the formation of the effect. In other words, the Pareto chart can be used as the first step to improving the work environment. With a glance at the Pareto chart, everyone can see that two or three actions caused the most problems and that a large number of factors contributed very little to the problems. Therefore, a basis for understanding and common understanding between group members is created and precise goals are defined to achieve a certain amount of path improvement. Therefore, the current research in this section, for the reasons mentioned, aims to show the results obtained from the optimization of the multi-objective model in the form of Pareto fronts diagrams.

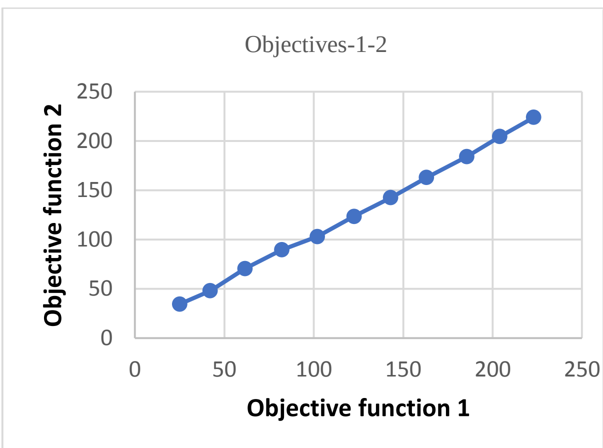

Fig. 3. Pareto front of quality level and time

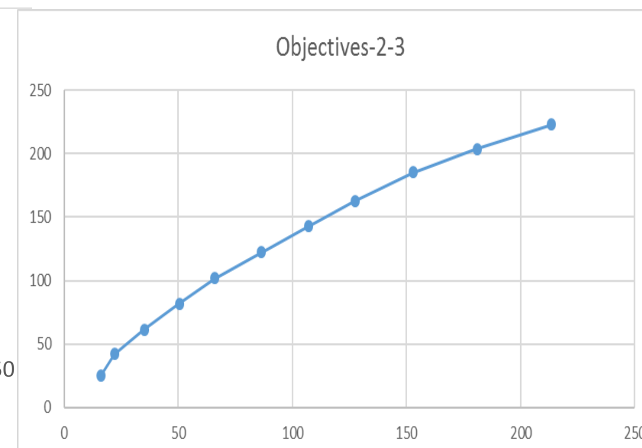

Fig. 4. Pareto front of cost and time

Figure (3) shows the Pareto front created based on quality and time-level objectives. As it is clear from the figure, there is a direct relationship between these two goals, which means that improving the quality level requires a long time. Figure (4) shows the Pareto front created between cost and time. According to this figure, the linear relationship between the two goals is evident.

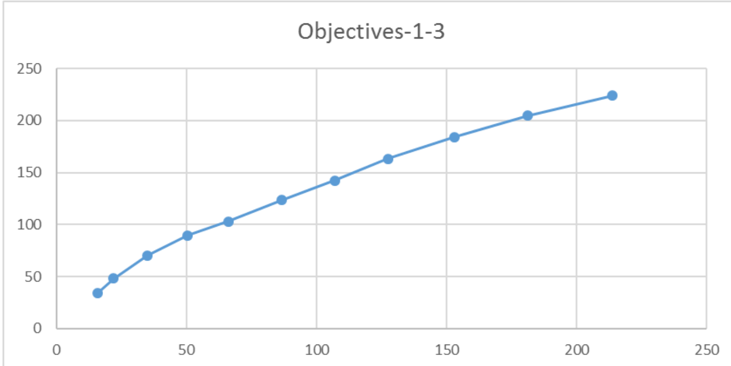

Fig. 5. The Pareto front created between quality and cost level objectives

Figure (5) shows the Pareto front created between quality and cost level objectives. The linear relationship between these goals indicates that to create a higher quality product, more funds are needed.

5-Managerial Insights

In this research, we have discovered all types of risks of oil and gas projects known to date. The results of this research make it possible to evaluate the risks, their impact and the probability of their occurrence. Then the risks are prioritized in the order of their importance. The last step is to decide on this risk and plan to respond to it. Therefore, the results of this research can help decision makers and managers a lot and solve their concerns. In this process, it will be necessary to determine who will be responsible for each risk and to develop a usable response for each risk. Risk response strategies are techniques used to reduce the effect or likelihood of identified or even unknown risks. Therefore, in terms of the risk strategy that should be used, the quantitative or qualitative assessment of the severity of the risk will guide how much time, money and effort should be spent on the strategy and to limit the risk. By comparing this research with Shafipour-Omrani et al. (2021), it can be said that considering a comprehensive approach to prioritizing investment risks and adopting a suitable strategy to properly respond to investment risks in oil and gas projects is among the innovations of our article compared to them.

6- Conclusions and suggestions

The purpose of this study is to identify and rank the effective risks in investing in the oil and gas industry. Based on the considered goal, in the first part of this study, the proposed problem, the desired questions, and operational and theoretical variables were stated. In the first part of the second part, the theoretical and conceptual foundations of the research were explained and the basic scientific concepts and documents related to the research were explained to explain the research topic. Next, in the second part, scientific research related to the research topic was given. The purpose of reviewing the conducted studies is to search for different information sources to study different aspects of the research topic and make a systematic comparison. The review of previous studies determines what has been done before in the field of current research and what is the application of the current research. Therefore, in this part of the second part, the number of 50 research studies from important aspects such as the purpose of the research, the adopted approach, and the obtained results were examined. The third part focuses on the research method and the tools used. In this section, taking into account the topic and purpose of the research, the research method was also stated and it was precisely specified what methods were used to achieve the results of this research. Considering the topic of the current research, the fuzzy Delphi approaches, the best-worst method, GRA-VIKOR, fuzzy logic, defined zero and one model, and the finiteness-epsilon approach are among the tools considered in this study.

In the fourth section, we sought to answer the questions considered for this study. This section was divided into two general sections, in the first section, the statistical population was described from different aspects, and in the second section, selected approaches were used. In the draft stage, following the investigations and consultation with oil and gas industry experts, 21 risks in the field of investment in this industry were compiled. In the second stage, using the fuzzy Delphi approach and consulting with 41 experts in this field in the oil and gas company, 6 risks were selected as the most critical risks. Before ranking these risks, 5 criteria were collected after conducting studies and scientific documents, and the weights of each of them were calculated through the best-worst approach. According to the criteria and weights of each of them, using the Fuzzy GRA-VIKOR approach, potential financial risks and the risk caused by sudden changes in inflation were identified as critical risks. Risks of sanctions by an institution or country, liquidity, health risks (such as the corona epidemic), financial potential, exchange rate fluctuations, and sudden changes in inflation were identified as critical risks, respectively. Another approach of interest in this study to identify critical risks is the combined GRA-VIKOR approach. Before stating the results obtained by this approach, it should be mentioned that the nature of Vikor's approach is not based on classification, but based on choosing the best option. Based on this, potential financial risks and the risk caused by sudden changes in inflation are the most critical risks identified with the GRA-VIKOR approach. In the last step, the current study sought to provide answers for each of the identified critical risks. For this purpose, after conducting scientific studies and also thinking together with the experts of the oil and gas company, several response strategies should be determined for each critical risk. To adopt the appropriate strategy for each of the risks, a zero and three-objective model was presented. And finally, the epsilon constraint multi-objective optimization approach was used to solve this three-objective model. After solving the three-objective model with the adopted approach and based on the results obtained with the adopted approaches, we will continue to express practical suggestions. Based on the results obtained, strategies to support domestic producers; Employing specialized forces and experts in the field of finance, training employees, integrated resource management system, adopting different approaches to reduce the effect of fluctuations, and considering the amount of foreign currency and Riyal as a combination in contracts, respectively, for the risks of sanctions by an institution or country. For liquidity risk, the risk caused by health risks (such as the corona epidemic), potential financial risks, the risk caused by exchange rate fluctuations, and the risk caused by sudden changes in inflation can be considered as practical proposals for the upcoming study.

To validate the results obtained from this research, we will compare and discuss the results obtained in this study with the results obtained from other research reviewed in the literature review. The purpose of this research is to identify and rank investment risks in the oil and gas industry. For this purpose, fuzzy Delphi approaches were used to identify risks, the best-worst approach was used to calculate the weights of the selected criteria for risk ranking, and the Fuzzy GRA-VIKOR approach was used for risk ranking. Also, a three-objective model was used to select response strategies for each critical risk, and this three-objective model was solved using the augmented epsilon constraint method. The investigation of the background of the research revealed that due to the wide importance of the oil and gas industry, this industry has been discussed from various aspects. It was also found that there was no community study that, in addition to identifying investment risks in this industry, ranked them using the Fuzzy GRA-VIKOR approach. Therefore, the results obtained from this research are not comparable with previous research and provide a framework for future evaluations and studies. Therefore, it is necessary to state that to discuss the results obtained from this study, the research works that had a more thematic affinity with the upcoming study were selected. In the first study, the research work done by Khalilzadeh et al. (2020) is referred to as a multi-objective mathematical model based on fuzzy hybrid decision-making methods and FMEA for the risks of oil and gas projects. This study was conducted with the aim of qualitative risk management of oil and gas projects (a case study of Pars Oil and Gas Company) and to answer the questions of what are the known risks of oil and gas construction projects. What are the possibilities, consequences, and priorities of the identified risks? What are the strategies to respond to these potential risks?

6-1- Suggestions for future research

Considering the subject of the current research, and the limitations we have faced during the research, the following suggestions can be considered as suggestions for future research works.

- Generalizing the subject of research to other areas and industries that face risk and need risk management.
- Applying other weighting approaches to obtain the weight and importance of the criteria.
- Using other decision-making approaches to identify and prioritize risks.

• In the current research, the multi-objective optimization approach is the "augmented epsilon-constraint" method. Since a wide range of classical multi-objective optimization approaches is available by reviewing the literature, it is suggested to consider other approaches.
• Using a mathematical programming approach for modeling instead of using multi-criteria decision-making methods.
• Using other methods that can take uncertainty into account, such as robust planning.
• Using other modeling methods such as simulation to investigate the behavior of a system in dealing with the risks under study and simultaneous optimization of the case study using simulation optimization models.

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