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A SUSTAINABLE DEVELOPMENT GOALS-BASED MATHEMATICAL MODEL FOR SELECTING OIL AND GAS INVESTMENT PROJECTS UNDER UNCERTAINTY AND LIMITED RESOURCES

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Abstract. In this study, a multi-period, multi-objective mathematical model is presented for selecting oil and gas investment projects based on the Sustainable Development Goals (SDGs) approach, considering resource limitations. Based on the economic dimension of sustainability, the profit from the implementation of petrochemical projects is maximized, and based on the environmental dimension, the amount of greenhouse gas emissions, energy consumption, and produced waste is minimized. According to the social dimension, the number of job opportunities, the number of people covered by insurance, the job satisfaction of employees, the project's impact on the regional economy, and the number of lost workdays is examined. The uncertainty of the strategic and operational parameters of the model has also been considered, and to deal with the uncertainty, fuzzy possibility programming (FPP) is used. The model is solved in GAMS optimization software with a two-stage approach based on fuzzy programming and the best-worst group decision-making method (BWM). Numerical results confirm the effectiveness of the proposed model and show that SDG will lead to a significant improvement in economic, environmental, and social dimensions without significantly reducing the profits of the selected oil and gas projects.

Keywords: Sustainable Development Goals (SDGs), Project selection, Resource constraints, Uncertainty, Fuzzy possibility planning (FPP), Best-Worst Method (BWM), Petrochemical industry.

AMS Subject Classification: 65-XX, 65Kxx, 65K10, 90-XX, 90Cxx.

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1 Introduction

Organizations' managers are always faced with conflicts in making decisions at different strategic and operational levels (Davardoost & Javadi, 2019) the quality and manner of these decisions will guarantee the success and survival of organizations in the field of business and will overshadow their competitive position. One of the critical determinations made by managers in petrochemical organisations is the selection of an optimal portfolio of investment projects from the available options. In the absence of quantitative and economic methodologies guiding the project selection process, there is a risk of misalignment between project outcomes and initial expectations, resulting in significant costs for both organizations and contractors. It is imperative for managers to employ mathematical optimization models to arrive at optimal decisions, thereby enabling them

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to quantitatively assess the outcomes of their decision-making and available options. Hence, the application of mathematical modelling in the assessment of oil and gas projects is of considerable importance for managers functioning in this sector. Through the utilization of the most efficient solution obtained from the mathematical model, managers can augment their capacity to make informed decisions (Afanasyev et al., 2023; Bilbao-Terol et al., 2006; Golmakani & Fazel, 2011; Kukharova et al., 2021; Liu & Gao, 2006). In general, the goal of the project selection problem is to choose an optimal portfolio of several selected projects according to the limitations of time, machinery, power, human capital, and other available facilities to achieve optimal goals. One of the important and commonly used goals in this field is to maximize the profit of the project and minimize the costs. Considering that the selection of oil and gas investment projects is one of the most important organization's decisions, paying attention only to the goals of the internal project stakeholders, such as the project sponsor, the employer, contractors, the project managers, the project consultant, and the main external stakeholders of the project, cannot be of great benefit to the managers and companies. Therefore, it cannot ensure the success and survival of the organization in the business environment. If an organization or company acts only based on profit to decide regarding the selection of the project and the satisfaction of the external stakeholders of the project, such as competitors, media, legislative organizations, environmentalists, sub-stakeholders, society, and citizens, if they do not pay attention, they may face a challenge in the long run. Therefore, to fulfill the main goals of managers in choosing investment projects, it is necessary to model the problem from the perspective of both internal and external stakeholders of the project. Carrying out any project requires the consumption of various renewable and non-renewable resources such as manpower, machinery, raw materials, and required equipment (Arefiev & Afanaseva, 2022). It is noteworthy that the execution of any oil and gas venture results in the emission of greenhouse gases into the atmosphere (Fetisov et al., 2023; Litvinenko et al., 2020; Pashkevich & Danilov, 2023). In recent years, there has been a growing global awareness of pollution control in response to production and industrial activities, driven by a desire to preserve land and its resources, promote economic development, ensure social welfare, protect the environment, and enhance community security (Fetisov et al., 2023; Ilyushin, 2022; Ilyushin & Fetisov, 2022; Litvinenko et al., 2023). According to the available statistics and reports, the emission of greenhouse gases around the world has increased by more than 80% from 1970 to 2010, which is considered a great threat to the global ecosystem (Martirosyan & Ilyushin, 2022). To reduce greenhouse gas emissions, different international agreements have been made. For example, China and the United States, as the largest emitters of carbon dioxide (CO2), announced their joint announcement on climate change in 2014 and policies to reduce greenhouse gas emissions. Then, at the United Nations (UN) Climate Conference in 2015, a new global agreement was made in which all participants pledged to reduce greenhouse gas emissions to zero (Chen & Chen, 2017; Yurak et al., 2020). In light of growing environmental concerns, business managers have devoted a significant portion of their efforts to executing effective investment projects that account for environmental considerations, in order to address these concerns (Martirosyan et al., 2021) by implementing projects in addition to increasing profitable sales and reducing costs (Kazanin & Drebenshtedt, 2017; Perdan & Azapagic, 2011).

Conversely, in the context of executing an investment initiative project, the organization's social responsibility towards employees, customers, and society should be considered with social goals such as increasing job opportunities, stabilizing employment, and reducing the number of injuries and lost days due to work accidents (Ilyushin et al., 2019; Moreno-Monsalve et al., 2023). In recent years, there has been an increased focus on the concept of sustainability, which involves balancing economic, social, and environmental requirements. With the growth of the world population and the increase of human activity, sustainability has become an important issue for governments, people, and environmentalists. Using sustainable development management for organizations will have many benefits, including customer satisfaction, cost control, innovation, and flexibility (Moreno-Monsalve et al., 2023; Rohmer et al., 2019; Sahebjamnia et al., 2018;

Taleizadeh et al., 2019). Although much research has been conducted in the field of investment project selection, based on the results of the research background, limited research has been conducted in the field of investment project selection according to Sustainable Development Goals (SDGs). On the other hand, the decisions about selecting oil and gas investment projects are among the strategic decisions of petrochemical organizations that are faced with considerable uncertainty. The project selection problem encompasses numerous parameters, including the potential profit yielded by project implementation, the availability of manpower, the quantity of machines and raw materials necessary, the precise timing of activities, the requisite budget, and the costs associated with both manpower and raw materials. The requirement for the machine's cost is faced with significant uncertainty (Teplyakova et al., 2022). Considering these parameters in a certain way, the optimal solution to the problem may not be justified in real conditions. Ben-Tal & Nemirovski (2000) demonstrated that even with a mere 0.001% uncertainty in the parameters, the optimal solution derived from deterministic data is not sufficiently justified with a significant probability. Consequently, the constraints of the problem may be violated. Hence, it appears imperative to scrutinize the ambiguity surrounding the choice of investment ventures (Ben-Tal & Nemirovski, 2000).

The aim of this research is to provide a mathematical model for selecting investment oil and gas projects based on SDGs and considering the parameter's uncertainty. In this model, the goals of profit maximization, environmental impact minimization, and social impact maximization will be considered simultaneously. Since the available resources for the implementation of petrochemical projects are limited, in the mathematical model, the total budget available in a period will be considered limited, and the real world's limitations such as manpower, machines, and consumable resources will also be considered. Decision-making related to the selection of petrochemical projects is considered over a multi-period time horizon, and the investment and selection of those projects in each period will be examined separately.

The advantage of a multi-period, multi-objective mathematical model for selecting oil and gas investment projects compared with existing ones lies in its ability to comprehensively consider various factors and objectives over time, leading to more informed and strategic decision-making. This approach integrates multiple criteria and time periods, allowing for a holistic evaluation of investment projects. The previous studies also emphasize the advantages of rule-oriented models in decision support systems for oil and gas production companies, highlighting the need to utilize knowledge base rule-oriented models for decision-making. This aligns with the multi-objective nature of investment project selection, as it requires the consideration of diverse rules and criteria. Furthermore, it underscores the adaptability of techniques preferred by organizations, indicating that the multi-period, multi-objective mathematical model can be tailored to suit the specific preferences and needs of the oil and gas company.

In conclusion, the advantage of the multi-period, multi-objective mathematical model for selecting oil and gas investment projects compared with existing ones lies in its comprehensive consideration of diverse criteria, rules, and time periods, leading to more robust and informed decision-making processes.

The subsequent section of this manuscript delves into the background of the investigation, while the third section introduces the suggested mathematical framework. The fourth section presents a potential approach utilizing fuzzy programming to address the indeterminate nature of the parameters. The fifth section of the study delves into the methodology employed for resolving the model. The sixth and seventh sections entail the numerical results and sensitivity analysis, respectively. The final section provides conclusions and recommendations for future research.

2 Research background

In the literature on the selection of investment projects, various mathematical models have been developed for the selection of projects. This section provides a comprehensive review of the literature pertaining to the process of selecting investment projects. For this purpose, Table 1 presented below provides a summary of the solving methods proposed by scholars. It is noteworthy to mention that in the selection of investment projects, since numerous parameters of the real world are subject to uncertainty, mathematical modeling also takes uncertainty into account. To investigate uncertainty, various methods such as Monte Carlo simulation, stochastic programming, fuzzy theory, robust optimization, and hybrid approaches have been used.

While SDGs have been the subject of numerous research articles in recent years, the matter of selecting oil and gas investment projects has received comparatively less attention. Therefore, the characteristics of the reviewed articles are shown in Table 2. As can be seen in most of the research, only the economic dimension in the selection of projects with the aim of minimizing the implementation costs or maximizing the profit from the implementation of the project has been investigated, and other main dimensions of the SDGs, including environmental and social dimensions, have received less attention. Among the reviewed articles, only Habibi et al. (Habibi et al., 2019) used SDGs to select the suppliers of materials needed for the projects, and Reza Hosseini et al. (RezaHoseini et al., 2020) used SDGs to determine the desirability of the selected projects. Although in the real world it is rare to determine the exact value of the parameters, in most of the articles the parameters are assumed to be definite. Also, among the various methods to deal with the uncertainty of parameters, areas such as possible fuzzy optimization have not been considered at all. Interrelationships between projects have not been investigated in most studies. In this research, a model for selecting oil and gas investment projects based on SDGs is proposed in conditions of uncertainty, given the interdependent nature of projects and resource constraints, the present study proposes a model that innovatively addresses these factors as below which is mostly modeled on Zarinpour's work:

1. Providing a mathematical framework for the selection of petrochemical investment projects over a multi-period time horizon. The model considers various real-world constraints, including budgetary limitations, manpower availability, machinery capacity, raw material availability, and supplier capacity,

2. Investigating mutual relationships between projects using complementary economic constraints and incompatible options at the same time,

3. Examining the SDGs in the selection of oil and gas investment projects, including the economic, environmental, and social goals,

4. Examining job opportunities, injuries, and lost days due to work accidents, the number of people covered by insurance, the impact of project selection on the improvement of the regional economy, and the social welfare of employees in the function of the social goal,

5. Investigating greenhouse gas emissions, energy consumption, and waste produced in the review function for environmental purposes,

6. Investigating the uncertainty of real-world parameters and using the fuzzy possibility approach based on the "Me" criterion to deal with uncertainty in the project selection problem,

7. Using a combined solution approach, including the Best-Worst group method (BWM) to determine the weight of environmental and social factors and the interactive fuzzy programming method to solve the multi-objective mathematical model.

Table 1: Summary of models and proposed solving methods by scholars since 2010

Authors(year)	*Proposed model*	*Proposed solving method*	*Ref.*
Rabbani et al.(2010)	A multi-objective mathematical model for project selection, in which the objectives of project benefit maximization, risk minimization and total cost were investigated	Particle swarm optimization algorithm	(Rabbani et al., 2010)
Shakhsi-Niaei et al.(2011)	A project selection model under the uncertainty considering a limited budget. Firstly, they ranked the candidate projects through Monte Carlo simulation and a multi-criteria decision-making approach, and in the second stage, they proposed an integer programming model to select the final set of projects	Mixed approach	(Shakhsi-Niaei et al., 2011)
Khalili-Damghani et al.(2012)	A multi-objective model for selecting projects considering profit and risk objectives	The TOPSIS method and the epsilon constraint method	(Khalili-Damghani et al., 2012)
Khalili-Damghani et al.(2013)	A multi-period multi-objective model for project selection under limited resource conditions	Fuzzy-TOPSIS implementation	(Khalili-Damghani et al., 2013)
Zaraket et al.(2014)	A mathematical model for selecting software projects and resource allocation, in which universities, software companies and potential projects of a country are examined with the aim of profit maximization	Meta-Heuristic methods	(Zaraket et al., 2014)
Huang and Zhao(2014)	Investigated the problem of selection and timing of research and development projects under the conditions of uncertainty of net income and investment costs	Genetic algorithm	(Huang & Zhao, 2014)
Huang et al.(2014)	A mean-variance optimization model for the optimal project selection problem based on resource and budget constraints, considering the uncertainty of initial costs and net cash flows	Meta-Heuristic methods	(Huang et al., 2014)
Shafahi and Haghani(2014)	An optimization model for the selection of contracting projects, in which the importance of activities performed by contractors is used as the most important non-monetary evaluation criterion	Genetic algorithm and Monte Carlo simulation	(Shafahi & Haghani, 2014)
Toufighian and Naderi(2015)	This study proposes a bi-criteria framework for project selection and scheduling that aims to simultaneously optimize the expected profit of the project and minimize resource utilization.	Meta-Heuristic methods	(Tofighian & Naderi, 2015)
Huang et al.(2016)	A mean-variance model and a mean-semi-variance model for the problem of selecting and scheduling optimal projects by considering the relationship and order of time sequence between projects	Meta-Heuristic methods	(Huang et al., 2016)
Tang et al(2017)	A mathematical model for selecting oil and gas projects under budget and production capacity constraints	Quadratic planning model and preference theory	(Tang et al., 2017)
Shariatmadari et al. (2017)	This study proposes two distinct methodologies for project selection and scheduling, namely an integrated resource management approach utilising mixed integer programming, and a hybrid approach combining heuristic algorithm and gravity search algorithm.	Meta-Heuristic methods	(Shariatmadari et al., 2017)
Amirian and Sahraeian(2017)	A mathematical model for the problem of project selection and scheduling using the theory of net cash flows of projects based on gray data	Monte Carlo simulation and algorithm based on frog jump	(Amirian & Sahraeian, 2017)
Kumar et al.(2018)	Investigated the problem of project selection and planning with the aim of maximizing the expected profit and considered two types of interdependence, i.e., constraints of incompatible options and constraints of economic complementarity	Meta-Heuristic methods	(Kumar et al., 2018)
Shafahi and Haghani(2018)	A mathematical model for project selection and scheduling, based on which some projects can be implemented in different phases, in which maximizes the net present value of future investments under budget constraints and reinvestment strategies	Hybrid integer programming model	(Shafahi & Haghani, 2018)
Habibi et al.(2019)	A model for ordering materials and scheduling projects, in which the suppliers of materials required for projects are selected based on sustainability criteria	Fuzzy sequential analysis method	(Habibi et al., 2019)
Miralinaghi et al.(2020)	A two-level mathematical model for the selection and scheduling of road construction projects based on game theory, in which an optimal set of projects is selected and scheduled in the first level, and in the second level, and the travel delay time in roads is minimized	Game theory methods	(Miralinaghi et al., 2020)
Abbasi et al.(2020)	A project selection model for the development of new products in which a balanced scorecard is used to select criteria. They also used a two-objective model to select projects with the objectives of profit maximization and risk minimization	Meta-Heuristic methods	(Abbasi et al., 2020)
Tavana et al.(2020)	An approach based on multi-criteria decision making and mathematical modeling to evaluate and select information technology projects. They evaluated and ranked the projects and then selected the best projects using a two-objective mathematical model with the objectives of profit maximization and project value maximization	The fuzzy TOPSIS method	(Tavana et al., 2020)
Rezahoseini et al.(2020)	A model for selecting and scheduling projects in which the attractiveness of projects is determined based on a utility function dependent on sustainability and projects splitting	Utility function dependent	(RezaHoseini et al., 2020)
Mavrotas and Makryelios(2021)	An approach based on Monte Carlo simulation and mathematical modeling to select R&D projects considering budget constraints	Monte Carlo simulation and mathematical modeling	(Mavrotas & Makryvelios, 2021)
Zolfaqhari and Mousavi(2021)	A project selection and scheduling model considering resource management, in which the uncertainty of parameters is modeled using an interval-valued fuzzy random uncertainty	Fuzzy methods	(Zolfaghari & Mousavi, 2021)
Hamidi Hesarsorkh et al.(2021)	A model for selecting R&D projects in the arbitration industry, in which financial planning and outsourcing policy are considered. Also, they considered the uncertainty of the parameters	Probabilistically robust optimization models	(Hesarsorkh et al., 2021)
Zarinpour and Zarinpour,(2022)	A model for selecting and scheduling projects in which the attractiveness of projects is determined based on a utility function dependent on sustainability and projects splitting	Fuzzy sequential analysis method	(Zarinpour et al., 2022)

Table 2. Characteristics of reviewed scholarly articles in the field of project selection with the approach of the SDGs from 2010 until present

Source	Objective function		Stability factors			Period		Parameters		Approach to deal with uncertainty					Rel. Between Projects		Solution Method		
	Single	Multi	Economical	Environmental	Social	Single	Multi	Certain	Uncertain	Monte Carlo Simulation	Stochastic Optimization	Fuzzy Theory	Gray Theory	Combined Approach	Compatible	Incompatible	Accurate	Heuristic	Meta-Heuristic
(Rabbani et al., 2010)		☑	☑				☑	☑								☑			☑
(Shakhsi-Niaei et al., 2011)	☑		☑			☑			☑	☑						☑	☑		
(Khalili-Damghani et al., 2012)		☑	☑				☑	☑									☑		
(Khalili-Damghani et al., 2013)		☑	☑				☑		☑			☑					☑		
(Zaraket et al., 2014)	☑		☑				☑	☑											☑
(Huang & Zhao, 2014)	☑		☑				☑		☑		☑				☑	☑			☑
(Huang et al., 2014)	☑		☑				☑		☑		☑								☑
(Shafahi & Haghani, 2014)	☑		☑			☑			☑	☑									☑
(Tofighian & Naderi, 2015)		☑	☑				☑	☑								☑			☑
(Huang et al., 2016)	☑		☑				☑		☑		☑				☑	☑			☑
(Tang et al., 2017)	☑		☑			☑		☑									☑		
(Shariatmadari et al., 2017)	☑		☑				☑	☑											☑
(Amirian & Sahraeian, 2017)		☑	☑				☑		☑	☑			☑		☑				☑
(Kumar et al., 2018)	☑		☑				☑	☑							☑	☑			☑
(Shafahi & Haghani, 2018)	☑		☑				☑	☑										☑	
(Habibi et al., 2019)		☑	☑	☑	☑		☑	☑											☑
(Miralinaghi et al., 2020)	☑		☑				☑	☑							☑		☑		
(Abbasi et al., 2020)		☑	☑				☑	☑								☑			☑
(Tavana et al., 2020)		☑	☑			☑		☑									☑		
(RezaHoseini et al., 2020)		☑	☑	☑	☑		☑	☑								☑	☑		
(Mavrotas & Makryvelios, 2021)	☑		☑			☑			☑	☑							☑		
(Zolfaghari & Mousavi, 2021)	☑		☑				☑		☑			☑					☑		
(Hesarsorkh et al., 2021)	☑		☑				☑		☑					☑			☑		
(Zarinpour et al., 2022)		☑	☑	☑	☑		☑		☑			☑			☑	☑	☑		
-		☑	☑	☑	☑		☑		☑			☑			☑	☑	☑		

3 Mathematical model

3.1 Statement of the problem

In this research, a multi-objective mathematical model is presented for choosing investment oil and gas projects using the SDGs approach. Since the available resources for the project's implementation are limited, in the mathematical model, the total available budget is considered for a limited period, and other real-world limitations such as manpower, machinery (Yungmeister et al., 2021), and consumables are also considered respectively (Yungmeyster et al., 2022). The amount of investment and the projects chosen for each period are both determined based on the decisions made in relation to the selection of projects, which are made with a long-term time horizon. In the proposed model, the interrelationships between the projects, the uncertainty of the parameters, and the project's raw material suppliers' capacity are examined. The assumptions of the proposed problem are as follows:

1. Decisions related to the selection of projects can be made over several time periods.
2. Complementary economic restrictions are considered in the selection of investment projects.
3. The manpower and raw materials required to carry out investment projects and project's raw material suppliers' capacity in each of the time periods is limited.
4. Some investment projects have incompatible options, so by choosing one of them, the next incompatible option will be removed.
5. The uncertainty in the model parameters is considered.

The sets defined in the mathematical model are as follows:

J: set of existing projects;
T: set of time periods;
R: set of raw materials;
M: set of machines;
L: set of human resources;
S: set of suppliers;
K: set of amenities for employees;
H_j: set of incompatible projects with the project j
E_j: set of economic complementary projects of project j.

3.2 Economical objective function

The main goal of choosing oil and gas investment projects is to maximize the profit, which is as follow:

$$Max\ Z_1 = TR - TC, \tag{1}$$

where the total revenue from the selection of projects is marked with TR and the total cost of implementing the projects is marked with TC, which expression 2 is considered as below:

$$TR = \sum_j \sum_t \tilde{p}_{jt} x_{jt}, \tag{2}$$

where $\tilde{p}_{jt}$ is the expected profit of the project j at time t and x_{jt} is a binary variable, where it is equal to 1 if project j is selected at time t, otherwise it is considered zero. To calculate TC total system costs including fixed investment, raw material supply, manpower, machinery, travel, and amenities costs are considered. The fixed investment cost of the project can comprise of expenses related to the acquisition of equipment and machinery essential for the project's execution, infrastructure development, land procurement, construction of buildings, landscaping, and procurement of vehicles, and the cost of issuing permits and initial feasibility studies. This type of cost is expressed according to expression :

$$\sum_j \sum_t \tilde{F}c_{jt} x_{jt}, \tag{3}$$

where $\tilde{F}c_{jt}$ is the fixed investment cost to implement project j at time t.

The cost of supplying raw materials consists of the purchase cost and the cost of ordering raw materials which are procured from different suppliers. The cost of supplying raw materials is calculated using expression 4:

$$\sum_r \sum_s \sum_j \sum_t \tilde{p}c_{srt} y_{rsjt} + \sum_r \sum_s \sum_j \sum_t \tilde{o}c_{rst} u_{rsjt}, \tag{4}$$

where $\tilde{p}c_{srt}$ is the cost of purchasing raw material r from supplier s at time t, y_{rsjt} is the amount of raw material type r supplied by supplier s for project j at time t, $\tilde{o}c_{rst}$ is the fixed cost of ordering raw material r supplied by supplier s at a time t, and u_{rsjt} is the binary variable that is equal to 1 if supplier s is selected to supply raw material type r for project j at time t, otherwise it is considered zero.

To implement the project, the cost of manpower is calculated based on the man-hour according to the following expression 5:

$$\sum_l \sum_j \sum_t \tilde{l}c_{lt} wh_l x_{jt}, \tag{5}$$

where $\tilde{l}c_{lt}$ is the cost per hour of labor l at time t and wh_l is the working hours of labor type l in each period.

Also, the cost of machines is calculated based on machine-hours required for the implementation of the project according to expression 6:

$$\sum_m \sum_j \sum_t \tilde{M}c_{mt} wh_m x_{jt}, \tag{6}$$

where $\tilde{M}c_{mt}$is the cost per hour of machine type m at time t and wh_m is the working hours of machine type m in each period.

Furthermore, the cost for transporting raw materials from the supplier to the project site is calculated according to the following expression 7:

$$\sum_r \sum_s \sum_j \sum_t \tilde{T}c_{rsjt} d_{sj} y_{rsjt}, \tag{7}$$

where $\tilde{T}c_{rsjt}$ is the transportation cost of the raw material type r from the supplier s for the implementation of the project j in time t and d_{sj} is the distance between the supplier s and the project implementation site j.

Finally, the cost of amenities for the employees involved in the project is also calculated according to the following:

$$\sum_k \sum_j \sum_t \tilde{S}c_{kjt} o_{kjt}, \tag{8}$$

where $\tilde{S}c_{kjt}$ is the cost of providing any type of amenities k for project employees j at time t and o_{kjt} is the binary variable equal to 1 in case of providing any type of amenities k for the project employees j at time t, and otherwise zero.

Considering that in evaluating the economic feasibility of the projects the period and the time value of money are very effective factors, the concept of discount rate has been used. According to the provided information, it can be inferred that the first expression will be elaborated in the subsequent manner: (ir is the discount rate in percentage)

$$\begin{gathered} Max\ \mathrm{Z}_1 = \sum_t \frac{1}{(1+ir)^{t-1}} \left[\sum_j \tilde{p}_{jt} x_{jt} - \sum_j \tilde{F}c_{jt} x_{jt} - \sum_s \sum_r \sum_j \tilde{p}c_{srt} y_{rsjt} - \right. \\ - \sum_r \sum_s \sum_j \tilde{o}c_{rst} u_{rsjt} - \sum_l \sum_j \tilde{l}c_{lt} wh_l x_{jt} - \sum_m \sum_j \tilde{M}c_{mt} wh_m x_{jt} - \\ \left. - \sum_r \sum_s \sum_j \tilde{T}c_{rsjt} d_{sj} y_{rsjt} - \sum_k \sum_j \tilde{S}c_{kjt} o_{kjt} \right]. \end{gathered} \tag{9}$$

3.3 Environmental objective function

To execute a project, it is imperative to procure requisite raw materials, which necessitates the utilization of vehicles for the purpose of transporting materials from suppliers. The transportation of raw materials results in the emission of significant quantities of greenhouse gases, including carbon dioxide, methane, sulfur dioxide, nitrogen oxide, heavy metals, and volatile organic compounds (Fetisov et al., 2023). These emissions pose a severe threat to human health. The emission of greenhouse gases resulting from the combustion of fossil fuels is widely recognized as the primary contributor to global warming and consequential alterations in the Earth's climate and soil (Martirosyan & Ilyushin, 2022; Shammazov et al., 2023; Vasilyeva, 2023; Zhang et al., 2018). Conversely, the transportation of raw materials by vehicles necessitates the utilization of fossil fuels. The global populace's requirement for non-renewable energy sources is escalating at a rapid pace, surpassing the capacity of current energy reservoirs to cater to this mounting demand. According to a projection (Mirhosseini et al., 2011), the global energy demand is expected to increase twofold or even threefold by the year 2050. As per the prognostications, the worldwide utilization of oil is anticipated to escalate from 86 million barrels per diem in 2007 to 104 million barrels per day in 2030 (Brink & Marx, 2013; Ilyushin & Asadulagi, 2023). The preservation of fossil fuels has become an imperative need considering their depletion and the pressing environmental issues (Afanaseva et al., 2023; Kazakov et al., 2022).

To mitigate the quantity of greenhouse gas emissions resulting from the conveyance of raw materials, the fuel consumption associated with the transportation of materials from suppliers to the designated project site, and the waste generated by the utilization of raw materials in the chosen projects, we shall employ expressions 10, 11, and 12, correspondingly.

$$\sum_r \sum_s \sum_j \sum_t \tilde{g}h_{rsj} d_{sj} y_{rsjt}, \tag{10}$$

$$\sum_r \sum_s \sum_j \sum_t \tilde{e}_{rsj} d_{sj} y_{rsjt}, \tag{11}$$

$$\sum_r \sum_j \sum_t \tilde{w}g_{rj} x_{jt}, \tag{12}$$

where $\tilde{g}h_{rsj}$ is the amount of greenhouse gas emitted to transport raw material type r from supplier s to the project j, $\tilde{e}_{rsj}$ is the amount of fuel required to transport the raw material type r from supplier s to project j, and $\tilde{w}g_{rj}$ is the percentage of waste produced due to the use of raw material type r in project j.

According to the importance of greenhouse gas emissions, fuel consumption, and the production of waste, the environmental objective function will be as follows:

$$\begin{aligned} Min\ Z_2 = We_1 \left[\sum_r \sum_s \sum_j \sum_t \tilde{g}h_{rsj} d_{sj} y_{rsjt}\right] + We_2 \left[\textstyle\sum_r \sum_s \sum_j \sum_t \tilde{e}_{rsj} d_{sj} y_{rsjt}\right] + \\ +We_3 \left[\sum_r \sum_j \sum_t \tilde{w}g_{rj} x_{jt}\right]. \end{aligned} \tag{13}$$

Here $We_1,\ We_2,$ and We_3 are the weights of greenhouse gas emissions, the weight of the amount of fuel consumed, and the weight of the amount of waste produced, respectively.

3.4 Social objective function

With the implementation of any investment project, the organization's social responsibility towards internal and external stakeholders should be considered. The GRI report [36] has been used to consider the social dimension. One of the most important responsibilities of investors towards society is to increase the number of job opportunities. To implement an investment project, different human resources, such as project sponsors, employers, project managers, project consultants, project contractors, main project shareholders, and workers, are needed. It is worth noting that some of the required labor force is required on a constant basis from the beginning to the end of the project, but some of them will be employed for a short period of time. The number of fixed and variable job opportunities created by selecting investment projects is calculated as expressions (14) and (15). Then, the number of idle working days that are lost due to injuries and work hazards is calculated as below

$$\sum_j \sum_t \tilde{f}o_{jt} x_{jt}, \tag{14}$$

GRI is an independent international organization that provides sustainability reports based on all SDG aspects.

$$\sum_j \sum_t \tilde{v}o_{jt} x_{jt}, \tag{15}$$

$$\sum_j \sum_t \tilde{I}d_{jt} x_{jt}, \tag{16}$$

where $\tilde{f}o_{jt}$ is the number of fixed job opportunities created by choosing project j at a time t, $\tilde{v}o_{jt}$ is the number of variable job opportunities created by choosing project j at a time t, and $\tilde{I}d_{jt}$ is number of idle working days caused by choosing project j at a time t.

Given that project employers and contractors frequently hire erratic labor for numerous projects, insurance typically covers a small number of people. Therefore, to increase the number of people covered by insurance (objective function 17), to improve the economic situation of the project implementation area (objective function 18), and to increase the level of employee satisfaction, considering welfare amenities (objective function 19) as parts of the social objective function is considered respectively:

$$\sum_j \sum_t \tilde{f}sc_{jt} x_{jt}, \tag{17}$$

$$\sum_j \sum_t \tilde{p}_{jt} x_{jt}, \tag{18}$$

$$\sum_k \sum_j \sum_t \tilde{J}s_{kjt} o_{kjt}, \tag{19}$$

where $\tilde{f}sc_{jt}$ is the number of workers covered by insurance by choosing project j at a time t, $\tilde{p}_{jt}$ is the impact of the project's implementation j in time t on the economy of the region, and $\tilde{J}s_{kjt}$ is the employee's job satisfaction as a result of welfare services type k in project j at time t.

Considering the weight of each of the project's social responsibility objectives, the social objective's function will be as follows:

$$Max\ Z_3 = Ws_1 \left[\sum_j \sum_t (\tilde{f}o_{jt} + \tilde{v}o_{jt}) x_{jt}\right] + Ws_2 \left[-\sum_j \sum_t \tilde{I}d_{jt} x_{jt} + \sum_j \sum_t \tilde{f}sc_{jt} x_{jt}\right] +$$
$$+ Ws_3 \left[\sum_j \sum_t \tilde{p}_{jt} x_{jt}\right] + Ws_4 \left[\sum_k \sum_j \sum_t \tilde{J}s_{kjt} o_{kjt}\right], \tag{20}$$

where Ws_1 represents the weight assigned to the number of job opportunities created, Ws_2 represents the weight assigned to safety and health activities for employees, Ws_3 represents the weight assigned to the economic development of the region, and Ws_4 represents the weight assigned to employee amenities.

3.5 Constraints of the proposed problem

The constraints to the problem are taken as

$$\sum_t x_{jt} \leq 1, \tag{21}$$

$$\sum_t \left(t + \widetilde{du}_j\right) x_{jt} \leq T + 1, \tag{22}$$

$$\sum_j \widetilde{\lambda}_{rj} x_{jt} \leq \beta_{rt}, \quad \forall r, t, \tag{23}$$

$$\sum_j \widetilde{\gamma}_{mj} x_{jt} \leq \widetilde{\delta}_{mt}, \quad \forall m, t, \tag{24}$$

$$\sum_j \widetilde{\tau}_{lj} x_{jt} \leq \widetilde{\Omega}_{lt}, \quad \forall l, t, \tag{25}$$

$$\sum_t x_{jt} + \sum_t x_{ht} \leq 1, \quad \forall j, h \in H_j, \tag{26}$$

$$\sum_t x_{jt} = \sum_t x_{kt}, \quad \forall j, k \in E_j, \tag{27}$$

$$\sum_r \sum_s \sum_t y_{rsjt} = \sum_t \sum_r \widetilde{\lambda}_{rj} x_{jt}, \ \forall j, \tag{28}$$

$$\sum_s \sum_j y_{rsjt} = \beta_{rt}, \quad \forall r, t, \tag{29}$$

$$y_{rsjt} \leq \tilde{c}ap_{rs} u_{rsjt}, \quad \forall r, s, j, t, \tag{30}$$

$$u_{rsjt} \leq x_{jt}, \quad \forall r, s, j, t, \tag{31}$$

$$x_{jt} \in \{0, 1\}, \quad \forall j, t, \tag{32}$$

$$y_{rsjt} \geq 0, \quad \forall r, s, j, t, \tag{33}$$

$$u_{rsjt} \in \{0, 1\}, \quad \forall r, s, j, t, \tag{34}$$

$$o_{kjt} \in \{0, 1\}, \quad \forall k, j, t, \tag{35}$$

$$\beta_{rt} \geq 0, \ \forall r, t. \tag{36}$$

Constraint 21 guarantees that each project is selected only once in each period. According to constraint 22, each project must be completed within the planned time horizon. Constraint 23 specifies that the total raw materials required to carry out the selected projects should not exceed the available raw materials in any period ($\widetilde{\lambda}_{rj}$ is the required type r raw material for the project j in each period, and β_{rt} is the amount of primary material type r at time t). Constraint 24 states that the working hours of the machines required for the selected projects do not exceed the available machine-hours in any period ($\widetilde{\gamma}_{mj}$ is the required machine-hours type m for project j in each period, and $\widetilde{\delta}_{mt}$ is machine-hours available type m at time t). Based on the constraint 25, the man-hours required to carry out the selected projects do not exceed the available man-hours in any period ($\widetilde{\tau}_{lj}$ is the number of man-hours required for labor l for project j in each period, and $\widetilde{\Omega}_{lt}$ is man-hours available type l at time t). Constraint 26 is related to incompatible project options: if the projects are incompatible, only one of them will be selected. Constraint 27 expresses the restriction of economic complementarity between projects. Constraint 28 specifies that in each project, the total raw materials purchased from suppliers are equal to the raw materials needed to complete that project. Constraint 29 specifies that the total raw material purchased from suppliers is equal to the available raw material in each period. According to the constraint 30, the number of raw materials purchased must be less than the capacity of the suppliers. Constraint 31 specifies that only if a project is selected, suppliers will be selected to provide raw materials. The constraint of 32 to 36 specifies the constraints of the problem's decision variables.

4 A probabilistic fuzzy programming approach

In the previous section's proposed model, some parameters are uncertain. Approaches such as random optimization (RO), fuzzy optimization (FO), stable optimization, and hybrid approaches can be used to deal with parameter uncertainty. In this study, the fuzzy optimization method (FOM) is used to deal with the uncertainty in the parameters of the model. In fuzzy mathematical programming (FMP) models, fuzzy confidence coefficients and membership functions are used to express the uncertainty of parameters (Xu & Zhou, 2013; Zarrinpoor et al., 2018). Numerous researchers have used the fuzzy-probabilistic method that Xu and Zhou (Xu & Zhou, 2013) first proposed because of its widespread success. This method relies on strong mathematical concepts such as expected distance and the expected value of fuzzy numbers. In this method, it is assumed that all non-deterministic parameters follow the triangular distribution function. Consider the possibility space $(\theta,\ P(\theta),\ PoS)$ where $\theta,\ P(\theta)$, and PoS specify an arbitrary set, a set function of θ, and a possibility criterion, respectively. To determine the values of non-deterministic parameters between optimistic and pessimistic constraints, Xu, and Zhou (Zhang et al., 2018) used the Me criterion as follow:

$$Me(A) = Nec(A) + \varsigma(Pos(A) - Nec(A)), \tag{37}$$

where A is an arbitrary set in $P(\theta)$,and ς is an optimistic-pessimistic parameter that reflects the decision-makers opinions. Functions $Pos(A)$ and $Nec(A)$ specify the necessity and possibility of set A in probabilistic space, respectively. In the following, the approach of Xu and Zhou (2013) is briefly described. Consider the following linear programming model:

$$\begin{aligned} & Min\,\tilde{C}x \\ & \tilde{A}x \geq \tilde{b} \\ & \tilde{N}x \leq \tilde{d} \\ & x \geq 0. \end{aligned} \tag{38}$$

In this model, non-deterministic parameters are considered triangular fuzzy numbers (TFN). In probabilistic planning based on criterion 1, the functions of expected value, chance limit, and possibility limit are used. So, we have:

$$\begin{aligned} & Min\,\tilde{C}x \\ & Me\{\tilde{A}x \geq \tilde{b}\} \geq \alpha \\ & Me\{\tilde{N}x \leq \tilde{d}\} \geq \beta \\ & x \geq 0, \end{aligned} \tag{39}$$

where α and β are the minimum levels of satisfying the possible constraints. Xu, and Zhou converted the above model into upper approximation model (UAM) and a lower approximation model (LAM), and then, they proposed the deterministic equivalent (DE) model of the probabilistic models UAM and LAM, which are as follows:

Upper Approximation Model (UAM)

$$\begin{aligned} & Min\,E[\tilde{C}]x \\ & Pos\{\tilde{A}x \geq \tilde{b}\} \geq \alpha \\ & Pos\{\tilde{N}x \leq \tilde{d}\} \geq \beta \\ & x \geq 0 \end{aligned} \tag{40}$$

Lower Approximation Model (LAM)

$$\begin{aligned} & Min\,E[\tilde{C}]x \\ & Nec\{\tilde{A}x \geq \tilde{b}\} \geq \alpha \\ & Nec\{\tilde{N}x \leq \tilde{d}\} \geq \beta \\ & x \geq 0 \end{aligned} \tag{41}$$

The deterministic equivalent model of the probabilistic model UAM is in the form

$$\begin{array}{l} Min\ \left(\frac{1-c}{2}C_1+\frac{1}{2}C_2+\frac{c}{2}C_3\right)x \\ A_2x+(1-\alpha)(A_3-A_2)x\geq b_2-(1-\alpha)(b_2-b_1) \\ N_2x-(1-\beta)(N_2-N_1)x\leq d_2+(1-\beta)(d_3-d_2) \\ x\geq 0. \end{array} \tag{42}$$

The deterministic equivalent model of the probabilistic model LAM is

$$\begin{array}{l} Min\ \left(\frac{1-c}{2}C_1+\frac{1}{2}C_2+\frac{c}{2}C_3\right)x \\ A_2x+\alpha(A_2-A_1)x\geq b_2+(1-\alpha)(b_3-b_2) \\ N_2x+(1-\beta)(N_3-N_{21})x\leq d_2-\beta(d_2-d_1) \\ x\geq 0. \end{array} \tag{43}$$

Considering the possible planning method based on criteria, the deterministic equivalent model of the proposed non-deterministic problem based on UAM will be as follows

$$\begin{array}{l} Max\ Z_1=\sum\limits_t\frac{1}{(1+ir)^{t-1}}[\sum\limits_j\left(\frac{1-\varsigma}{2}p_{jt}^{(1)}+\frac{1}{2}p_{jt}^{(2)}+\frac{\varsigma}{2}p_{jt}^{(3)}\right)x_{jt}- \\ \sum\limits_j\left(\frac{1-\varsigma}{2}Fc_{jt}^{(1)}+\frac{1}{2}Fc_{jt}^{(2)}+\frac{\varsigma}{2}Fc_{jt}^{(3)}\right)x_{jt}- \\ \sum\limits_s\sum\limits_r\sum\limits_j\left(\frac{1-\varsigma}{2}pc_{srt}^{(1)}+\frac{1}{2}pc_{srt}^{(2)}+\frac{\varsigma}{2}pc_{srt}^{(3)}\right)y_{rsjt}- \\ \sum\limits_r\sum\limits_s\sum\limits_j\left(\frac{1-\varsigma}{2}oc_{rst}^{(1)}+\frac{1}{2}oc_{rst}^{(2)}+\frac{\varsigma}{2}oc_{rst}^{(3)}\right)u_{rsjt}- \\ \sum\limits_l\sum\limits_j\left(\frac{1-\varsigma}{2}lc_{lt}^{(1)}+\frac{1}{2}lc_{lt}^{(2)}+\frac{\varsigma}{2}lc_{lt}^{(3)}\right)wh_lx_{jt}- \\ \sum\limits_m\sum\limits_j\left(\frac{1-\varsigma}{2}Mc_{mt}^{(1)}+\frac{1}{2}Mc_{mt}^{(2)}+\frac{\varsigma}{2}Mc_{mt}^{(3)}\right)wh_mx_{jt}- \\ \sum\limits_r\sum\limits_s\sum\limits_j\left(\frac{1-\varsigma}{2}Tc_{rsjt}^{(1)}+\frac{1}{2}Tc_{rsjt}^{(2)}+\frac{\varsigma}{2}Tc_{rsjt}^{(3)}\right)d_{sj}y_{rsjt}- \\ \sum\limits_k\sum\limits_j\left(\frac{1-\varsigma}{2}Sc_{kjt}^{(1)}+\frac{1}{2}Sc_{kjt}^{(2)}+\frac{\varsigma}{2}Sc_{kjt}^{(3)}\right)o_{kjt}]; \end{array} \tag{44}$$

$$\begin{array}{l} Min\ Z_2=We_1\left[\sum\limits_r\sum\limits_s\sum\limits_j\sum\limits_t\left(\frac{1-\varsigma}{2}gh_{rsj}^{(1)}+\frac{1}{2}gh_{rsj}^{(2)}+\frac{\varsigma}{2}gh_{rsj}^{(3)}\right)d_{sj}y_{rsjt}\right]+ \\ We_2\left[\sum\limits_r\sum\limits_s\sum\limits_j\sum\limits_t\left(\frac{1-\varsigma}{2}e_{rsj}^{(1)}+\frac{1}{2}e_{rsj}^{(2)}+\frac{\varsigma}{2}e_{rsj}^{(3)}\right)d_{sj}y_{rsjt}\right]+ \\ We_3\left[\sum\limits_r\sum\limits_j\sum\limits_t\left(\frac{1-\varsigma}{2}wg_{rj}^{(1)}+\frac{1}{2}wg_{rj}^{(2)}+\frac{\varsigma}{2}wg_{rj}^{(3)}\right)x_{jt}\right]; \end{array} \tag{45}$$

$$\begin{array}{l} Max\ Z_3=Ws_1\left[\sum_j\sum_t\left(\frac{1-\varsigma}{2}fo_{jt}^{(1)}+\frac{1}{2}fo_{jt}^{(2)}+\frac{\varsigma}{2}fo_{jt}^{(3)}\right)x_{jt}+\sum_j\sum_t\left(\frac{1-\varsigma}{2}vo_{jt}^{(1)}+\frac{1}{2}vo_{jt}^{(2)}+\frac{\varsigma}{2}vo_{jt}^{(3)}\right)x_{jt}\right]+ \\ Ws_2\left[-\sum_j\sum_t\left(\frac{1-\varsigma}{2}Id_{jt}^{(1)}+\frac{1}{2}Id_{jt}^{(2)}+\frac{\varsigma}{2}Id_{jt}^{(3)}\right)x_{jt}+\sum_j\sum_t\left(\frac{1-\varsigma}{2}fsc_{jt}^{(1)}+\frac{1}{2}fsc_{jt}^{(2)}+\frac{\varsigma}{2}fsc_{jt}^{(3)}\right)x_{jt}\right]+ \\ Ws_3\left[\sum_j\sum_t\left(\frac{1-\varsigma}{2}p_{jt}^{(1)}+\frac{1}{2}p_{jt}^{(2)}+\frac{\varsigma}{2}p_{jt}^{(3)}\right)x_{jt}\right]+Ws_4\left[\sum_k\sum_j\sum_t\left(\frac{1-\varsigma}{2}js_{kjt}^{(1)}+\frac{1}{2}js_{kjt}^{(2)}+\frac{\varsigma}{2}js_{kjt}^{(3)}\right)o_{kjt}\right]. \end{array} \tag{46}$$

Subject to (21), (26), (27), (29), (31)-(36)

$$\sum_t \left(t + \left[du_j^{(2)} - (1-\beta)\left(du_j^{(2)} - du_j^{(1)}\right)\right]\right) x_{jt} \le T + 1, \quad \forall j \tag{47}$$

$$\sum_j \left[\lambda_{rj}^{(2)} - (1-\beta)\left(\lambda_{rj}^{(2)} - \lambda_{rj}^{(1)}\right)\right] x_{jt} \le \beta_{rt}, \quad \forall r,\ t \tag{48}$$

$$\sum_j \left[\gamma_{mj}^{(2)} - (1-\beta)\left(\gamma_{mj}^{(2)} - \gamma_{mj}^{(1)}\right)\right] x_{jt} \le \delta_{mt}^{(2)} + (1-\beta)\left(\delta_{mt}^{(3)} - \delta_{mt}^{(2)}\right), \quad \forall m,\ t \tag{49}$$

$$\sum_j \left[\tau_{lj}^{(2)} - (1-\beta)\left(\tau_{lj}^{(2)} - \tau_{lj}^{(1)}\right)\right] x_{jt} \le \Omega_{lt}^{(2)} + (1-\beta)\left(\Omega_{lt}^{(3)} - \Omega_{lt}^{(2)}\right), \quad \forall l,\ t \tag{50}$$

$$\sum_r \sum_s \sum_t y_{rsjt} \ge \sum_t \sum_r \lambda_{rj}^{(2)} x_{jt}, \quad \forall j \tag{51}$$

$$\sum_r \sum_s \sum_t y_{rsjt} \le \sum_t \sum_r \lambda_{rj}^{(3)} x_{jt}, \quad \forall j \tag{52}$$

$$y_{rsjt} \le \left[cap_{rs}^{(2)} + (1-\beta)\left(cap_{rs}^{(3)} - cap_{rs}^{(2)}\right)\right] u_{rsjt}, \quad \forall r,\ s,\ j,\ t. \tag{53}$$

The deterministic equivalent model of the proposed non-deterministic problem based on LAM will be as follows:

$$Max\ E\left(Z_1\right),$$

$$Min\ E\left(Z_2\right),$$

$$Max\ E\left(Z_3\right).$$

Subject to (21), (26), (27), (29), (31)-(36), (51), (52)

$$\sum_t \left(t + \left[du_j^{(2)} + (1-\beta)\left(du_j^{(3)} - du_j^{(2)}\right)\right]\right) x_{jt} \le T + 1, \quad \forall j \tag{54}$$

$$\sum_j \left[\lambda_{rj}^{(2)} + (1-\beta)\left(\lambda_{rj}^{(3)} - \lambda_{rj}^{(2)}\right)\right] x_{jt} \le \beta_{rt}, \quad \forall r,\ t \tag{55}$$

$$\sum_j \left[\gamma_{mj}^{(2)} + (1-\beta)\left(\gamma_{mj}^{(3)} - \gamma_{mj}^{(2)}\right)\right] x_{jt} \le \delta_{mt}^{(2)} - \beta\left(\delta_{mt}^{(2)} - \delta_{mt}^{(1)}\right), \quad \forall m,\ t \tag{56}$$

$$\sum_j \left[\tau_{lj}^{(2)} + (1-\beta)\left(\tau_{lj}^{(3)} - \tau_{lj}^{(2)}\right)\right] x_{jt} \le \Omega_{lt}^{(2)} - \beta\left(\Omega_{lt}^{(2)} - \Omega_{lt}^{(1)}\right), \quad \forall l,\ t \tag{57}$$

$$y_{rsjt} \le \left[cap_{rs}^{(2)} - \beta\left(cap_{rs}^{(2)} - cap_{rs}^{(1)}\right)\right] u_{rsjt}, \quad \forall r,\ s,\ j,\ t. \tag{58}$$

5 Solution method

In this study, a two-step solution method is used. In the first stage, the importance of environmental and social criteria is determined using the best-worst method (BWM). In the second step, an interactive fuzzy programming method will be used to transform the multi-objective mathematical programming problem into a single-objective problem.

5.1 The Best-Worst Method (BWM)

BWM was introduced in 2015 to determine the weight of decision-making problem criteria (Rezaei, 2015). In this study, considering that this method only uses the preferences of a decision maker, to determine the weight of the criteria based on the opinions of a group of decision makers, the BWM of Omrani et al. (2020) has been used. The steps of this method are summarized as follows:

1. Step 1. Determine the important criteria for the decision problem.
2. Step 2. determine the best and worst criteria from each decision maker's perspective.
3. Step 3. Specify the preference of the best criterion (B) over the rest of the criteria based on the opinion of the decision maker (r) with numbers 1 to 9 as follows:

$$A_B^r = (a_{B1}^r,\ a_{B2}^r, \ldots, a_{Bn}^r)\,. \tag{59}$$

4. Step 4. Specify the preference of other criteria over the worst criteria (W) based on the decision maker's opinion (r) with numbers 1 to 9 as follows:

$$A_W^r = (a_{1W}^r,\ a_{2W}^r, \ldots, a_{nW}^r)\,. \tag{60}$$

5. Step 5. Considering a_{Bo}^r, the preference of the best criterion (B) over criterion o based on the opinion of decision maker r and a_{oW}^r, the preference of the criterion o over the worst criterion (W) based on the opinion of the decision maker (r), determine the optimal weight of each criterion based on the following model:

$$Min \sum_r \xi_r \tag{61}$$

$$|\omega_B - a_{Bo}^r \omega_o| \le \xi_r, \quad \forall o, r \tag{62}$$

$$|\omega_0 - a_{oW}^r \omega_W| \le \xi_r, \quad \forall o, r \tag{63}$$

$$\sum_0 \omega_o = 1, \tag{64}$$

$$\omega_o \ge 0. \tag{65}$$

Considering that the above-mentioned model is nonlinear, its linear form is written as follows:

$$Min \sum_r \xi_r \tag{66}$$

Subject to (64), (65)

$$\omega_B - a_{Bo}^r \omega_o \le \xi_r, \tag{67}$$

$$\omega_B - a_{Bo}^r \omega_o \ge -\xi_r, \quad \forall o, r \tag{68}$$

$$\omega_o - a_{oW}^r \omega_W \le \xi_r, \tag{69}$$

$$\omega_o - a_{oW}^r \omega_W \ge -\xi_r, \quad \forall o, r \tag{70}$$

5.2 Interactive fuzzy programming (IFP) method

To solve multi-objective problems, there are various methods, such as the Epsilon constrained method (ECM), the LP-metric method, and the weighted sum method (WSM). In this study, the interactive fuzzy programming method (IFPM) proposed by Torabi and Hassini (Torabi & Hassini, 2008) is used to solve multi-objective problems. In this approach, positive ideal solutions (PIS) and negative ideal solutions (NIS) for the objective functions of the problem are calculated as follows:

$$Z_1^{PIS} = \ Min\ Z_1 = Max\ Z_1, Z_1^{NIS}, \tag{71}$$

$$Z_2^{PIS} = Max\ Z_2 \quad = Min\ Z_2, Z_2^{NIS}, \tag{72}$$

$$Z_3^{PIS} = Min\ Z_3 \quad = Max\ Z_3, Z_3^{NIS}. \tag{73}$$

The linear membership function (LMF) for each of the objective functions is also defined as follows:

$$\mu_1 (Z_1) = \begin{cases} 1, \quad Z_1 > Z_1^{PIS} \\ \frac{Z_1 - Z_1^{NIS}}{Z_1^{PIS} - Z_1^{NIS}}, \quad Z_1^{NIS} \le Z_1 \le Z_1^{PIS} \\ 0, \quad Z_1 < Z_1^{NIS} \end{cases} \tag{74}$$

$$\mu_2 (Z_2) = \begin{cases} 1, \quad Z_2 < Z_2^{PIS} \\ \frac{Z_2^{NIS} - Z_2}{Z_2^{NIS} - Z_2^{PIS}}, \quad Z_2^{PIS} \le Z_2 \le Z_2^{NIS} \\ 0, \quad Z_2 > Z_2^{NIS} \end{cases} \tag{75}$$

$$\mu_3 (Z_3) = \begin{cases} 1, \quad Z_3 > Z_3^{PIS} \\ \frac{Z_3 - Z_3^{NIS}}{Z_3^{PIS} - Z_3^{NIS}}, \quad Z_3^{NIS} \le Z_3 \le Z_3^{PIS} \\ 0, \quad Z_3 < Z_3^{NIS} \end{cases} \tag{76}$$

The following expressions are used to convert the multi-objective model into a single-objective model:

$$Max\ \lambda (x) = \varphi \lambda_0 + (1 - \varphi) \sum_h \varpi_h \mu_h (x) \tag{77}$$

$$\lambda_0 \le \mu_h (x), \qquad \forall h \tag{78}$$

$$x \in F (x), \ \lambda_0, \ \varphi \in [0, \ 1]. \tag{79}$$

where ϖ_h, $F(x)$ and φ determine the relative importance of objective function h, the solution space of the problem and the compensation coefficient, respectively. Also, $\lambda_0 = \min_h \mu_h (x)$ and $\mu_h(x)$ determine the membership degrees of objective function h.

6 Numerical results

In this section, solution methods are used to explain the numerical results of the proposed model's solution. Table 3 shows the values of the input parameters in numerical examples. To determine the weight of the components of the environmental and social objective functions, the opinions of five experts in the field of investment projects were used.

Table 3. Values of the input parameters in numerical examples

Parameters	Quantity	Parameters	Quantity
$\widetilde{\mathbf{p}}_{\mathbf{j}t}$	[100000000, 500000000]	$\widetilde{\Omega}_{lt}$	[0, 30]
$\widetilde{\mathbf{Fc}}_{\mathbf{j}t}$	[3000000, 21000000]	d_{sj}	[0, 150]
$\widetilde{\mathbf{pc}}_{\mathbf{s}rt}$	[2000, 5000]	$\tilde{e}_{rsj}$	[5, 20]
$\widetilde{\mathbf{oc}}_{\mathbf{r}st}$	[5000, 6000]	$\tilde{g}h_{rsj}$	[1, 5]
$\widetilde{\mathbf{Mc}}_{\mathbf{m}t}$	[1000, 4000]	$\tilde{f}o_{jt}$	[3, 10]
$\widetilde{\mathbf{lc}}_{\mathbf{l}t}$	[8000, 30000]	$\tilde{v}o_{jt}$	[4, 10]
$\widetilde{\mathbf{Sc}}_{\mathbf{k}jt}$	[3000, 12000]	$\tilde{I}d_{jt}$	[5, 8]
$\widetilde{\mathbf{Tc}}_{\mathbf{r}sjt}$	[10, 30]	$\tilde{j}s_{kjt}$	[0, 0.8]
$\mathbf{i}r$	10%	$\tilde{p}_{jt}$	[0.02, 0.04]
$\widetilde{\lambda}_{\mathbf{r}j}$	[0, 20]	wh_l	[0, 8]
$\widetilde{\tau}_{\mathbf{l}j}$	[0, 10]	wh_m	[0, 8]
$\widetilde{\gamma}_{\mathbf{m}j}$	[0, 20]	$\tilde{c}ap_{rs}$	[200, 1000]
$\widetilde{\delta}_{\mathbf{m}t}$	[0, 50]	$\tilde{d}u_j$	[1, 10]

Table 4 shows the preference of the best criterion (B) over other criteria and the preference of other criteria over the worst criterion (W) for environmental and social factors. In this table, the amount of greenhouse gas emissions is shown with (e_1), the amount of energy consumption with (e_2), and the amount of produced waste with (e_3). And, in the same table, the preference of decision makers according to social criteria is presented. In this table, the number of job opportunities created by (s_1), safety and health activities for employees by (s_2), economic development of the region by (s_3), and amenities by (s_4) are demonstrated. Tables 5 also shows the optimal weight of environmental and social criteria.

Table 4. The preference of decision makers according to environmental and social criteria

Decision Makers	***The best and worst criteria***	***The criteria***						
		$\mathbf{e_1}$	$\mathbf{e_2}$	$\mathbf{e_3}$	$\mathbf{s_1}$	$\mathbf{s_2}$	$\mathbf{s_3}$	$\mathbf{s_4}$
DM_1	The best criteria (e_2) and (s_2)	6	1	9	9	1	5	4
	The worst criteria (e_3) and (s_1)	7	9	1	1	9	7	6
DM_2	The best criteria (e_1) and (s_3)	1	7	8	9	5	1	6
	The worst criteria (e_3) and (s_1)	8	6	1	1	6	9	5
DM_3	The best criteria (e_2) and (s_2)	5	1	9	7	1	5	9
	The worst criteria (e_3) and (s_4)	6	9	1	5	9	6	1
DM_4	The best criteria (e_2) and (s_3)	4	1	9	9	5	1	6
	The worst criteria (e_3) and (s_1)	7	9	1	1	7	9	6
DM_5	The best criteria (e_1) and (s_3)	1	6	8	5	4	1	9
	The worst criteria (e_3) and s_4)	8	7	1	5	6	9	1

Table 5. The optimal weight of environmental and social criteria

Criteria	e_1	e_2	e_3	s_1	s_2	s_3	s_4
The weight of the criteria	0.4908	0.2908	0.2181	0.1851	0.3333	0.3333	0.1481

Five different examples are used for numerical results. The model is coded in GAMS optimization software (Released May 18, 2023). The size of the sets of numerical examples is shown in Table 6, and the numerical results obtained from solving the model are shown in Table 7. In Table 7, (DE) specifies the value of the objective function in linear mode. As can be seen, the profit from the implementation of projects in all numerical examples in the UAM model is greater than that in the LAM model. Because the UAM model is based on an optimistic view, the profit from the implementation of projects (ς) increases with the increase in the optimistic opinions of the decision makers. When the profit of the projects increases, more projects will be selected, and more raw materials will be needed to implement the projects. Vehicles are used to transport raw materials from suppliers to the project site which results in large amounts of greenhouse gases and energy. Therefore, the value of the environmental objective function increases. The value of the social objective function also increases in proportion to the profit of the project. Because, when more projects are selected, more job opportunities will be created.

Since the focus is mostly on the economic dimension in the project selection models, the impact of sustainability dimensions on the selection of investment projects has been investigated. Table 8 shows the results based on the third numerical example. In this table, SM is a proposed model based on SDGs, and PM is a model considering the maximization of expected profit. As can be seen, considering the SDGs, the result of the economic objective function in deterministic models (UAM and LAM) will decrease by 0.13%, 1.19%, and 0.13%, respectively, though it will significantly improve the environmental and social objective functions. The destructive environmental effects in the deterministic models (UAM and LAM) in the PM model are 2.31, 2.82, and 2.25 times of those of the model considering sustainability, respectively. The social objective function of the deterministic and UAM models in the SM case has been improved by 95.4 and 98.97 percent, respectively, compared to the PM case. The social objective function of LAM is also 2.06 times that of PM in the SM case.

Table 6. The size of the sets of numerical examples

Numerical examples	**|J|**	**|T|**	**|R|**	**|M|**	**|L|**	**|S|**	**|K|**
1	5	7	3	2	2	3	2
2	10	8	5	4	3	4	3
3	15	9	7	5	4	5	4
4	21	11	9	6	5	6	5
5	28	13	11	7	6	7	6

Table 7. The numerical results obtained from solving the model.

Num. Example	ς	DE			LAM			UAM		
		Z1	Z2	Z3	Z1	Z2	Z3	Z1	Z2	Z3
1	0.1				1.055431E+09	1666.97	14.94	1.055933E+09	16513.59	14.94
	0.5	1.099333E+09	19509.49	15.07	1.099331E+09	17851.87	1528	1.222557E+09	18661.64	14.54
	0.9				1.267020E+09	21169.94	15.51	1.269248E+09	21101.11	1556
2	0.1				2.475251E+09	63923.82	42.59	2.522687E+09	62829.95	42.14
	0.5	2.313894E+09	72458.03	48.07	2.568655E+09	73116.49	44.76	2.617890E+09	71794.83	43.83
	0.9				2.662044E+09	82000.59	46.94	2.713062E+09	80454.86	45.51
3	0.1				2.634490E+09	86794.27	68.72	3.056598E+09	88016.78	6992
	0.5	3.321070E+10	128851.35	72.93	2.733912E+09	98732.59	71.82	3.171957E+09	100055.37	72.7
	0.9				2.836510E+09	110377.66	74.99	3.290475E+09	111791.82	75.57
4	0.1				3.764156E+09	139677.04	115.25	4.419160E+09	155742.70	126.39
	0.5	4.585755E+09	189041.01	130.33	3.906262E+09	157318.41	123.53	4.585805E+09	174262.42	134.14
	0.9				4.048238E+09	174274.08	131.87	4.752523E+09	192530.84	141.89
5	0.1				5.000652E+09	210721.98	193.98	5.645970E+09	244567.81	203.04
	0.5	5.599354E+09	246673.12	196.63	5.176357E+09	229478.49	199.61	5.859659E+09	274324.41	213.97
	0.9				5.378069E+09	259817.99	213.75	6.109869E+09	322146.32	221.33

Table 8. Comparison of the proposed model and profit maximization model for model 3

	D		**LAM**		**UAM**	
	PM	**SM**	**PM**	**SM**	**PM**	**SM**
Z1	3.214945E+09	3.210700E+09	2.766536E+09	2.733912E+09	3.214971E+09	3.210752E+09
Z2	297095.431	128851.352	278935.149	98732.595	264165.827	117210.973
Z3	37.321	72.927	34.934	71.818	37.404	74.423
m1	1.000	0.999	1.000	0.988	1.000	0.987
m2	0.605	0.829	0.592	0.856	0.639	0.863
m3	0.423	0.826	0.448	0.921	0.451	0.877

7 Sensitivity analysis

This section presents an analysis of the variations in the objective function concerning the parameters of φ, discount rate (ir), available person-hours, and available machine-hours, utilizing numerical example number 5.

7.1 The effect of φ on the objective functions

To investigate the effect of φ on the objective functions, the value of the degree of membership in each function has been investigated. Table 9 shows the effect of φ on the objective functions. As can be seen, with the increase in the value of the membership degree of the first objective function, the membership degree of the second objective function decreases and the membership degree of the second objective function increases. The degree of membership in the third objective function also has no special trend. Of course, in each of the deterministic models, UAM and LAM, for some values of φ, the membership degree of the function remains unchanged. Also, the results of the investigation of effect of φ on the objective functions shows that results from DE, UAM and LAM are convergent to 0.870 (Figure 1).

Table 9. The effect of φ on the objective functions

φ	**D**			**LAM**			**UAM**		
	m1	**m2**	**m3**	**m1**	**m2**	**m3**	**m1**	**m2**	**m3**
0	0.999	0.829	0.826	0.988	0.856	0.921	0.999	0.840	0.898
0.1	0.999	0.829	0.826	0.988	0.856	0.921	0.999	0.840	0.898
0.2	0.999	0.829	0.826	0.988	0.856	0.921	0.987	0.863	0.877
0.3	0.999	0.829	0.826	0.988	0.856	0.921	0.987	0.863	0.877
0.4	0.999	0.829	0.826	0.988	0.856	0.921	0.987	0.863	0.877
0.5	0.999	0.829	0.826	0.988	0.856	0.921	0.987	0.863	0.877
0.6	0.910	0.849	0.883	0.988	0.856	0.921	0.987	0.863	0.877
0.7	0.868	0.861	0.873	0.920	0.879	0.886	0.987	0.863	0.877
0.8	0.868	0.861	0.873	0.920	0.879	0.886	0.877	0.877	0.880
0.9	0.868	0.861	0.873	0.920	0.879	0.886	0.877	0.877	0.880
1	0.868	0.861	0.865	0.892	0.879	0.879	0.877	0.877	0.880

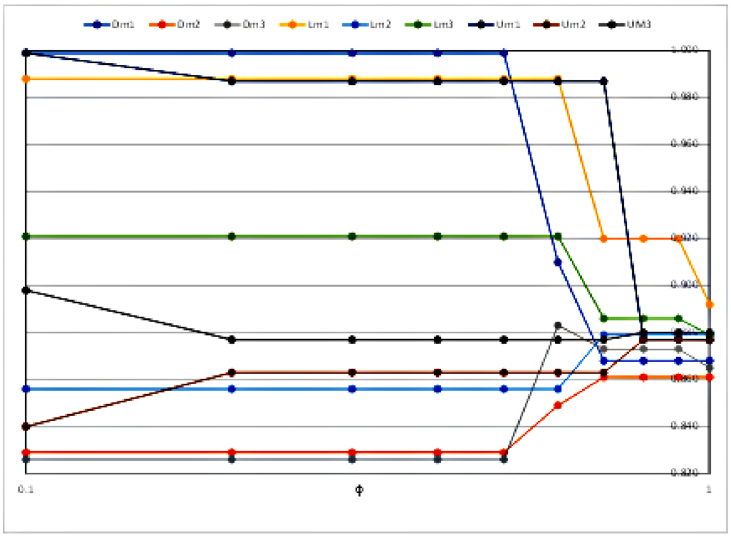

Figure 1: The results of the investigation of effect of φ on the objective functions

7.2 The Effect of discount rate (ir) on the objective functions

The effect of the discount rate (ir) on the objective functions is shown in Table 10 and figure 2. As can be seen, with the increase in the ir, the total profit decreases. Also, in some cases, the environmental objective function and the social objective function are relatively reduced and remain constant. It should be noted that the discount rate is one of the most influential parameters on the profit obtained from the oil and gas project's implementation which by considering it, a profitable project may be considered uneconomical. Considering that both the income and expenses of the investor are affected by the discount rate (ir), profitable projects should be selected according to the discount rate (ir) and the time factor (t).

Table 10. The effect of the discount rate (ir) on the objective functions

ir	D			LAM			UAM		
	Z1	Z2	Z3	Z1	Z2	Z3	Z1	Z2	Z3
5%	3.706272E+09	122862.295	74.208	3.279311E+09	98732.595	71.818	3.963227E+09	117210.973	74.423
10%	3.010700E+09	118851.352	72.927	2.733912E+09	98732.595	71.818	3.210752E+09	117210.973	74.423
15%	2.475420E+09	113102.470	71.913	2.328027E+09	97971.445	70.421	2.677894E+09	96795.550	71.309
20%	2.121001E+09	113102.470	71.913	2.000735E+09	97971.445	70.421	2.285416E+09	96795.550	71.309
25%	1.815055E+09	107071.860	70.953	1.735980E+09	97971.445	70.421	1.978719E+09	93977.590	70.393

The results of the analysis show that the closest exponential trend line for the objective functions is $y = 4E + 09e^{-0.178x}$, $R^2 = 0.995$ (Figure 2).

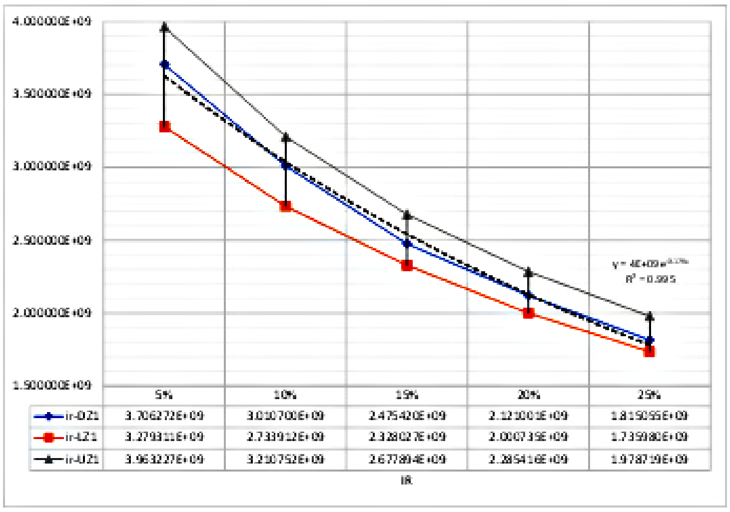

Figure 2: The effect of the discount rate (ir) on the objective functions

7.3 The impact of available machine-hours and maximum available person-hours on objective functions

The impact of the maximum available machine hours is shown in Table 11. In this table, the first column shows the percentage of maximum machine-hour changes compared to the base state. By increasing the available machine hours in each period, more projects can be implemented, and the profit from the implementation of investment projects in the oil and gas industry increases. As the number of selected projects increases, the environmental objective function and the social objective function also increase. In general, time is considered as an important factor in the profitability of the selected oil and gas projects, and if the machine hours available in the initial time periods of the project can provide the machine hours required by the project, a high profit will be obtained for the investors.

Also, the effect of the maximum available man-hours is shown in Table 12. As it can be seen, by increasing the maximum number of available man-hours, the necessary manpower to complete the projects is provided in less time, and the projects become profitable sooner than expected. Furthermore, by increasing the maximum available man-hours compared to the base case, as profitability increases, the economic impact of the project on the region and the number of available job opportunities increase, and as a result, the social objective function increases compared to the base case. With the increase in available man-hours, as more projects are selected, the amount of energy consumption and greenhouse gas emissions will increase, and the objective environmental function will increase, respectively.

Table 11. The impact of the maximum available machine hours

%	D			LAM			UAM		
	Z1	**Z2**	**Z3**	**Z1**	**Z2**	**Z3**	**Z1**	**Z2**	**Z3**
-20	2.860279E+09	104865.812	72.343	2.456912E+09	77091.073	67.057	2.906881E+09	109696.826	73.605
-10	2.906878E+09	120567.874	72.570	2.546337E+09	82988.835	69.123	2.994517E+09	110234.723	74.510
0	3.210700E+09	128851.352	72.927	2.733912E+09	98732.595	71.818	3.210752E+09	117210.973	74.423
10	3.231657E+09	129761.187	73.422	2.816691E+09	116453.761	75.285	3.239712E+09	118921.188	75.634
20	3.254746E+09	131275.894	77.075	2.844017E+09	117065.666	77.617	3.254757E+09	119379.594	77.773

Table 12. The effect of the maximum available man-hours

%	D			LAM			UAM		
	Z1	**Z2**	**Z3**	**Z1**	**Z2**	**Z3**	**Z1**	**Z2**	**Z3**
-20	2.678142E+00	111749.693	70.974	2.524386E+00	94778.300	71.269	2.705919E+00	104271.254	71.678
-10	2.816719E+00	126699.774	71.891	2.671828E+00	97126.124	71.547	2.816723E+00	115391.996	72.285
0	3.210700E+00	128851.352	72.927	2.733912E+00	98732.595	71.818	3.210752E+00	117210.973	74.423
10	3.230857E+00	129687.173	79.409	2.994522E+00	100251.176	74.651	3.351887E+00	117878.958	79.060
20	3.288020E+00	130486.734	79.508	3.178685E+00	111155.371	76.661	3.380361E+00	118258.236	79.786

8 Conclusion

In this study, the multi-objective planning problem of choosing investment projects considering real-world limitations such as manpower, machinery, and consumables was presented. To select investment projects, in addition to the economic objective function that maximizes the profit from the implementation of the oil and gas projects, environmental and social objectives were also considered. The proposed model was considered a multi-cycle mathematical programming model. Based on the environmental dimension, the amount of greenhouse gas emissions, the amount of energy consumed to provide the required raw materials, and the amount of waste produced were minimized. Based on the social dimension, the number of job opportunities created by the selected projects, the number of people covered by insurance, the job satisfaction of employees because of the provision of welfare services, the impact of the project on the region's economy, and the number of lost working days were minimized. Also, the capacity of the suppliers to provide the raw materials needed by the projects and the costs of purchasing and ordering the raw materials were considered. Considering that in the real world, many parameters are uncertain and random in nature, the uncertainty of the parameters was also considered. To transform the non-deterministic model into a deterministic equivalent model, the fuzzy probability programming approach based on the *Me* criterion was used, and two LAM and UAM models were developed. To check the effectiveness of the proposed model, five different numerical examples were considered, and the results were presented based on economic, social, and environmental objective functions. In the end, the sensitivity analysis of the key parameters was presented.

Based on the numerical results, it can be stated that the presented mathematical model provides a suitable tool for decision-making regarding the evaluation and selection of projects for the senior managers of organizations and enables them to get the highest profit by choosing the best set of projects and thereby overshadow their competitive position accordingly. Since the UAM model is based on an optimistic view, in most of the numerical examples, the profit from the implementation of the projects is greater than the LAM and the deterministic equivalent model.

In UAM model, more projects are selected, so as the profit is higher, more energy will be consumed and more greenhouse gases will be emitted, so the environmental objective function in most numerical examples in UAM model is also higher than in LAM model. Also, UAM model has a higher social objective function than LAM model and is a deterministic model. Therefore, based on the numerical results, it can be stated that considering the SDGs will significantly improve the environmental and social dimensions of sustainability without having a significant impact on the profit of the project's implementation.

The results of this research show that if there is uncertainty in the model's parameters, they cannot be ignored. Because, the profitability of the investor is greatly affected, and the amount of profit will be less or more than the actual amount. The discount rate (ir) is one of the most influential parameters in investment; considering it, an economic project has a chance to may be considered uneconomical. Therefore, its exact amount should be determined according to the type of project so that the investor can choose profitable projects in the shortest possible time. In general, by increasing the maximum machine hours and the maximum person hours available, it becomes possible to carry out investment projects in a shorter period, and consequently, the profit from the project's implementation increases. Therefore, to design an effective project selection mathematical model, it is necessary to consider real-world constraints such as renewable and non-renewable resources for the implementation of projects to obtain an accurate estimate of the implementing projects' benefit.

9 Recommendations for the future research

According to the proposed model in this article, future research directions for researchers in the fields of investment and project management are suggested as follows:

In the proposed model, the maximum machine-hour and person-hour available in each period are considered parameters. It would be very interesting for future research to consider these parameters as decision variables. In the proposed model, the effect of loans, sanctions, currency exchange rate, and other financing sources on the implementation of projects can be considered.

In this study, fuzzy probabilistic programming was used to deal with uncertainty. For future research, other approaches such as robust optimization and stochastic planning (logic-based Bender's decomposition (LBBD) can be used to deal with uncertainty and compare the results with the possible fuzzy planning approach.

References

Abbasi, D., Ashrafi, M., & Ghodsypour, S.H. (2020). A multi objective-BSC model for new product development project portfolio selection. **Expert Systems with Applications**, 162, 113757.

Afanaseva, O., Bezyukov, O., Pervukhin, D., & Tukeev, D. (2023). Experimental Study Results Processing Method for the Marine Diesel Engines Vibration Activity Caused by the Cylinder-Piston Group Operations. **Inventions, 8**(3), 71.

Afanasyev, M., Pervukhin, D., Kotov, D., Davardoost, H., & Smolenchuk, A. (2023). System Modeling in Solving Mineral Complex Logistic Problems with the Anylogic Software Environment. *Transportation Research Procedia*, 68, 483-491.

Amirian, H., Sahraeian, R. (2017). Solving a grey project selection scheduling using a simulated shuffled frog leaping algorithm. *Computers & Industrial Engineering*, 107, 141-149.

Arefiev, I.B., Afanaseva, O.V. (2022). Implementation of Control and Forecasting Problems of Human-Machine Complexes on the Basis of Logic-Reflexive Modeling. In *System Analysis in Engineering and Control* (pp. 187-197). Springer.

Ben-Tal, A., Nemirovski, A. (2000). Robust solutions of linear programming problems contaminated with uncertain data. *Mathematical Programming*, 88, 411-424.

Bilbao-Terol, A., Pérez-Gladish, B., & Antomil-Lbias, J. (2006). Selecting the optimum portfolio using fuzzy compromise programming and Sharpe's single-index model. *Applied Mathematics and Computation, 182*(1), 644-664.

Brink, J., Marx, S. (2013). Harvesting of Hartbeespoort Dam micro-algal biomass through sand filtration and solar drying. *Fuel*, 106, 67-71.

Chen, J.-X., Chen, J. (2017). Supply chain carbon footprinting and responsibility allocation under emission regulations. J*ournal of Environmental Management*, 188, 255-267.

Davardoost, H., Javadi, M. (2019). Complexity and Conflict Management in Iran's Oil and Gas Projects Evidence from One of the South Pars Gas Field Development Phases. *International Conference on Innovations in Business administration and Economics.*

Fetisov, V., Davardoost, H., & Mogylevets, V. (2023). Technological Aspects of Methane–Hydrogen Mixture Transportation through Operating Gas Pipelines Considering Industrial and Fire Safety. *Fire, 6*(10), 409.

Fetisov, V., Gonopolsky, A.M., Davardoost, H., Ghanbari, A.R., & Mohammadi, A.H. (2023). Regulation and impact of VOC and CO2 emissions on low?carbon energy systems resilient to climate change: A case study on an environmental issue in the oil and gas industry. *Energy Science & Engineering, 11*(4), 1516-1535.

Fetisov, V., Gonopolsky, A.M., Zemenkova, M.Y., Andrey, S., Davardoost, H., Mohammadi, A.H., & Riazi, M. (2023). On the Integration of CO2 Capture Technologies for an Oil Refinery. *Energies, 16*(2), 865.

Golmakani, H.R., Fazel, M. (2011). Constrained portfolio selection using particle swarm optimization. *Expert Systems with Applications, 38*(7), 8327-8335.

Habibi, F., Barzinpour, F., & Sadjadi, S.J. (2019). A mathematical model for project scheduling and material ordering problem with sustainability considerations: A case study in Iran. *Computers & Industrial Engineering*, 128, 690-710.

Hesarsorkh, A.H., Ashayeri, J., & Naeini, A.B. (2021). Pharmaceutical R&D project portfolio selection and scheduling under uncertainty: A robust possibilistic optimization approach. Computers & Industrial Engineering, 155, 107114. Huang, X., Xiang, L., & Islam, S. M. (2014). Optimal project adjustment and selection. *Economic Modelling*, 36, 391-397.

Huang, X., Zhao, T. (2014). Project selection and scheduling with uncertain net income and investment cost. *Applied Mathematics and Computation,* 247, 61-71.

Huang, X., Zhao, T., & Kudratova, S. (2016). Uncertain mean-variance and mean-semivariance models for optimal project selection and scheduling. *Knowledge-Based Systems*, 93, 1-11.

Ilyushin, Y.V. (2022). Development of a Process Control System for the Production of High-Paraffin Oil. *Energies, 15*(17), 6462.

Ilyushin, Y.V., Asadulagi, M.A.M. (2023). Development of a Distributed Control System for the Hydrodynamic Processes of Aquifers, Taking into Account Stochastic Disturbing Factors. *Water, 15*(4), 770.

Ilyushin, Y.V., Fetisov, V. (2022). Experience of virtual commissioning of a process control system for the production of high-paraffin oil. *Scientific Reports, 12*(1), 18415.

Ilyushin, Y.V., Pervukhin, D.A., & Afanaseva, O.V. (2019). Application of the theory of systems with distributed parameters for mineral complex facilities management. *ARPN Journal of Engineering and Applied Sciences, 14*(22), 3852-3864.

Kazakov Yu.A., Garufullin, D., Korotkova, O.Y., & Agaguena, A. (2022). Analysis of the mobile complex structure for organogenic materials mining by in-pit method. Mining informational and analytical bulletin, 6, 317-330.

Kazanin, O.I., Drebenshtedt, K. (2017). Mining education in the XXI century: global challenges and prospects. *Journal of Mining Institute, 225*(0), 369. `https://doi.org/10.18454/pmi.2017.3.369`

Khalili-Damghani, K., Sadi-Nezhad, S., & Tavana, M. (2013). Solving multi-period project selection problems with fuzzy goal programming based on TOPSIS and a fuzzy preference relation. *Information Sciences*, 252, 42-61.

Khalili-Damghani, K., Tavana, M., & Sadi-Nezhad, S. (2012). An integrated multi-objective framework for solving multi-period project selection problems. *Applied Mathematics and Computation, 219*(6), 3122-3138.

Kukharova, T.V., Utkin, V.A., & Pershin, I.M. (2021). Modeling of a Decision Support System for a Psychiatrist Based on the Dynamics of Electrical Conductivity Parameters. 2021 *IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering* (ElConRus).

Kumar, M., Mittal, M.L., Soni, G., & Joshi, D. (2018). A hybrid TLBO-TS algorithm for integrated selection and scheduling of projects. C*omputers & Industrial Engineering*, 119, 121-130.

Litvinenko, V.S., Petrov, E.I., Vasilevskaya, D.V., Yakovenko, A.V., Naumov, I.A., & Ratnikov, M.A. (2023). Assessment of the role of the state in the management of mineral resources. *Journal of Mining Institute, 259*(0), 95-111. `https://doi.org/10.31897/PMI.2022.100`

Litvinenko, V.S., Tsvetkov, P.S., Dvoynikov, M.V., & Buslaev, G.V. (2020). Barriers to implementation of hydrogen initiatives in the context of global energy sustainable development. Journal of Mining Institute, 244(0), 428-438. `https://doi.org/10.31897/pmi.2020.4.5`

Liu, M., Gao, Y. (2006). An algorithm for portfolio selection in a frictional market. *Applied Mathematics and Computation, 182*(2), 1629-1638. https://doi.org/https://doi.org/10.1016/j.amc.2006.05.048

Martirosyan, A.V., Ilyushin, Y.V. (2022). The Development of the Toxic and Flammable Gases Concentration Monitoring System for Coalmines. *Energies, 15*(23), 8917.

Martirosyan, A.V., Ilyushin, Y.V. (2022, August). Modeling of the Natural Objects' Temperature Field Distribution Using a Supercomputer. In *Informatics* (Vol.9, No.3, p. 62). MDPI.

Martirosyan, A.V., Kukharova, T.V., & Fedorov, M.S. (2021). Research of the Hydrogeological Objects' Connection Peculiarities. 2021 *IV International Conference on Control in Technical Systems* (CTS)

Mavrotas, G., Makryvelios, E. (2021). Combining multiple criteria analysis, mathematical programming and Monte Carlo simulation to tackle uncertainty in Research and Development project portfolio selection: A case study from Greece. *European Journal of Operational Research, 291*(2), 794-806.

Miralinaghi, M., Seilabi, S.E., Chen, S., Hsu, Y.-T., & Labi, S. (2020). Optimizing the selection and scheduling of multi-class projects using a Stackelberg framework. European *Journal of Operational Research, 286*(2), 508-522.

Mirhosseini, M., Sharifi, F., & Sedaghat, A. (2011). Assessing the wind energy potential locations in province of Semnan in Iran. *Renewable and Sustainable Energy Reviews, 15*(1), 449-459.

Moreno-Monsalve, N., Delgado-Ortiz, M., Rueda-Varyn, M., & Fajardo-Moreno, W.S. (2023). Sustainable development and value creation, an approach from the perspective of project management. *Sustainability, 15*(1), 472.

Omrani, H., Amini, M., & Alizadeh, A. (2020). An integrated group best-worst method–Data envelopment analysis approach for evaluating road safety: A case of Iran. *Measurement*, 152, 107330.

Pashkevich, M.A., Danilov, A.S. (2023). Ecological security and sustainability. *Journal of Mining Institute, 260*(0), 153-154. https://pmi.spmi.ru/index.php/pmi/article/view/16233

Perdan, S., Azapagic, A. (2011). Carbon trading: Current schemes and future developments. *Energy Policy, 39*(10), 6040-6054.

Rabbani, M., Bajestani, M.A., & Khoshkhou, G.B. (2010). A multi-objective particle swarm optimization for project selection problem. *Expert Systems with Applications, 37*(1), 315-321.

Martirosyan, A.V., Ilyushin, Y.V. (2022, August). Modeling of the Natural Objects' Temperature Field Distribution Using a Supercomputer. In *Informatics* (Vol. 9, No. 3, p. 62). MDPI.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega,* 53, 49-57.

RezaHoseini, A., Ghannadpour, S.F., & Hemmati, M. (2020). A comprehensive mathematical model for resource-constrained multi-objective project portfolio selection and scheduling considering sustainability and projects splitting. *Journal of Cleaner Production*, 269, 122073.

Rohmer, S., Gerdessen, J.C., & Claassen, G. (2019). Sustainable supply chain design in the food system with dietary considerations: A multi-objective analysis. *European Journal of Operational Research, 273*(3), 1149-1164.

Sahebjamnia, N., Fathollahi-Fard, A.M., & Hajiaghaei-Keshteli, M. (2018). Sustainable tire closed-loop supply chain network design: Hybrid metaheuristic algorithms for large-scale networks. *Journal of Cleaner Production*, 196, 273-296.

Shafahi, A., Haghani, A. (2014). Modeling contractors' project selection and markup decisions influenced by eminence. *International Journal of Project Management, 32*(8), 1481-1493.

Shafahi, A., Haghani, A. (2018). Project selection and scheduling for phase-able projects with interdependencies among phases. *Automation in Construction*, 93, 47-62.

Shakhsi-Niaei, M., Torabi, S.A., & Iranmanesh, S.H. (2011). A comprehensive framework for project selection problem under uncertainty and real-world constraints. *Computers & Industrial Engineering, 61*(1), 226-237.

Shammazov, I.A., Batyrov, A.M., Sidorkin, D.I., & Van Nguyen, T. (2023). Study of the Effect of Cutting Frozen Soils on the Supports of Above-Ground Trunk Pipelines. *Applied Sciences, 13*(5), 3139. https://doi.org/10.3390/app13053139

Shariatmadari, M., Nahavandi, N., Zegordi, S.H., & Sobhiyah, M.H. (2017). Integrated resource management for simultaneous project selection and scheduling. *Computers & Industrial Engineering,* 109, 39-47.

Taleizadeh, A.A., Haghighi, F., & Niaki, S.T.A. (2019). Modeling and solving a sustainable closed loop supply chain problem with pricing decisions and discounts on returned products. *Journal of Cleaner Production*, 207, 163-181.

Tang, B.-J., Zhou, H.-L., & Cao, H. (2017). Selection of overseas oil and gas projects under low oil price. *Journal of Petroleum Science and Engineering*, 156, 160-166.

Tavana, M., Khosrojerdi, G., Mina, H., & Rahman, A. (2020). A new dynamic two-stage mathematical programming model under uncertainty for project evaluation and selection. *Computers & Industrial Engineering*, 149, 106795.

Teplyakova, A., Azimov, A., Alieva, L., & Zhukov, I. (2022). Improvement of manufacturability and endurance of percussion drill assemblies: Review and analysis of engineering solutions. *MIAB. Mining Inf. Anal. Bull.*, 9, 120-132.

Tofighian, A.A., Naderi, B. (2015). Modeling and solving the project selection and scheduling. *Computers & Industrial Engineering,* 83, 30-38.

Torabi, S.A., Hassini, E. (2008). An interactive possibilistic programming approach for multiple objective supply chain master planning. *Fuzzy Sets and Systems, 159*(2), 193-214.

Vasilyeva M.A., Volchikhina A.A., Kuskildin R.B. (2023). Improvement of water segregation in backfilling. *MIAB. Mining Inf. Anal. Bull.,* 4, 125-139. (In Russian). https://doi.org/10.25018/0236_1493_2023_4_0_125.
Vasilyeva M.A., Volochkina, A., Kuskildin, R.B. (2023). Improvement of water segregation in backfilling. *Mining Informational and Analytical Bulletin*, 4, 125-139. https://doi.org/10.25018/0236_1493_2023_4_0_125.

Xu, J., Zhou, X. (2013). Approximation based fuzzy multi-objective models with expected objectives and chance constraints: Application to earth-rock work allocation. *Information Sciences*, 238, 75-95.

Yungmeister, D., Gasimov, E., & Isaev, A. (2021). Substantiation of the design and parameters of the device for regulating the air flow in down-the-hole hammers of roller-cone drilling rigs. *MIAB, 6*(2), 251-267. https://doi.org/10.25018/0236_1493_2022_62_0_251

Yungmeyster, D., Isaev, A. & Gasymov, E.. (2022). Substantiation of dth air drill hammer parameters for penetration rate adjustment using air flow. *Gornyi Zhurnal*, 72-77. doi: 10.17580/gzh.2022.07.12.

Yurak, V.V., Dushin, A.V., & Mochalova, L.A. (2020). Vs sustainable development: scenarios for the future. *Journal of Mining Institute, 242*(0), 242. https://doi.org/10.31897/pmi.2020.2.242

Zaraket, F.A., Olleik, M., & Yassine, A.A. (2014). Skill-based framework for optimal software project selection and resource allocation. *European Journal of Operational Research, 234*(1), 308-318.

Zarinpour, N., Naimeh, Zarinpur, & Mohammadi, A.H. (2022). Presenting a mathematical model for selecting investment projects based on sustainable development goals under conditions of uncertainty and limited resources. *Industrial Engineering and Management, 38*(1), 51-66.

Zarrinpoor, N., Fallahnezhad, M.S., & Pishvaee, M.S. (2018). The design of a reliable and robust hierarchical health service network using an accelerated Benders decomposition algorithm. *European Journal of Operational Research, 265*(3), 1013-1032.

Zhang, S., Liu, L., Zhang, L., Zhuang, Y., & Du, J. (2018). An optimization model for carbon capture utilization and storage supply chain: A case study in Northeastern China. *Applied Energy*, 231, 194-206.

Zolfaghari, S., Mousavi, S.M. (2021). A novel mathematical programming model for multi-mode project portfolio selection and scheduling with flexible resources and due dates under interval-valued fuzzy random uncertainty. *Expert Systems with Applications*, 182, 115207.