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Developing a Mathematical Programming Model to Determine the Optimal Portfolio of Capital Projects in Oil and Gas Companies to Achieve the Strategic Goals

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Highlights

- Project portfolio management is a comprehensive framework for decision-making and selecting the portfolio of projects to achieve the organization's goals by considering resource constraints.
- The importance of this issue in Iran's oil and gas industry is even more remarkable than ever due to its unique position in the country's economy and capital-intensive and budget constraints that have intensified in recent years.
- This study is applied research in terms of objective and provides a pattern to determine the optimal portfolio of capital plans for oil and gas companies.
- The research studies one of the country's most important oil and gas-producing companies and the only offshore company.
- It determines a framework for selecting the optimal portfolio of capital projects.
- The zero–one integer linear mathematical programming model with the objective function of maximizing the net present value from fields is designed and solved by GAMS software.
- Finally, the best investment mode for each field and the optimal portfolio are defined.

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Abstract

Project portfolio management is a comprehensive framework for decision-making and selecting projects to attain organizational goals by considering resource constraints. The importance of this issue in Iran's oil and gas industry is even more remarkable than ever. This significance is due to its unique position in the country's economy and capital-intensive and capital budget constraints that have intensified recently. Identifying and defining different scenarios for each oil and gas field, determining the parameters of the mathematical model, determining the required data to calculate the model parameters, and identifying the process and methods of identifying this data indicate the distinction and necessity of this research. This study is applied research in terms of objective, using a mathematical modeling approach, which has provided a pattern to determine the optimal portfolio of capital plans of oil and gas companies. The research approach is a case study that has studied one of the country's most important oil and gas-producing companies and the only offshore company. It determines a framework for selecting the optimal portfolio of capital projects. After gathering the required data, the zero–one integer linear mathematical programming model with the objective function of maximizing the net present value from fields (as the company's strategic goal) by considering investment constraints is designed and solved by GAMS software. Finally, the best investment mode for each field and the optimal portfolio are defined according to the defined constraint.

Keywords: Linear Planning of Integers Zero and One, Oil and Gas Industry, Optimal Portfolio, Portfolio Optimization, Portfolio Management.

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1. Introduction

Nowadays, plans and projects are essential to the activities of companies. A significant amount of their income depends on the proper selection and implementation of projects, which is a prerequisite for the success of these organizations (Nikpey and Torabi, 2013). The organizational goals and the implementation of its strategies are attainable through projects (Arsanjani et al., 2012). Moreover, the expansion of project-based organizations in recent years and the lack of resources at the organizational level due to the prevailing conditions in the country's macro-economy are increasing. Therefore, optimal project management has become more critical (Barmayevar and Ebadati, 2018). According to the project portfolio management standard (PMI, version 2017), project portfolio management is the centralized management of one or more portfolios by identifying, prioritizing, delegating, managing, and controlling its plans and projects to achieve strategic goals. In project portfolio management, monitoring and evaluation criteria are upgraded from the project level to the organization's overall strategy level (Iranmanesh et al., 2010). A systematic framework for identifying, selecting, and prioritizing projects must be chosen arbitrarily or without a thorough review (Dorri et al., 2015).

The primary purpose of project portfolio management is to select and implement projects that can conclusively facilitate achieving the company's ultimate goals. Integrating project and organization goals can help organizations accomplish this (Jafarzadeh et al., 2018). Further, using project portfolio management causes the organization to gain benefits that cannot be obtained from the separate implementation of projects (Barmayevar and Ebadati, 2018). Therefore, projects with a higher value for the organization are given priority, and projects with a lower focus are selected in the following stages. This is necessary due to resource constraints, so project portfolio management is essential. One of the biggest challenges is ensuring that the organization's projects align with the company's management strategy due to limited resources. Since each project has its characteristics, it is challenging to implement this and requires a lot of investigation and care. Therefore, managers must create a balance between the projects' needs, stakeholders' expectations, and the entire organization's performance, according to which the organization's projects are to act to achieve the organization's goals (Nassif et al., 2013). The complexity of this issue and the consideration of various factors in the decision-making process have increased the interest and number of studies that use mathematical programming methods. This is due to the high efficiency of these methods in solving complex problems (Rabbani et al., 2010).

With increasing competition in global markets in recent decades, new projects form the basis of organizational success (Ma et al., 2019). Chu, Hsu, and Fehling conducted one of the first portfolio selection studies in 1996 to select an R&D portfolio (Mohagheghi et al., 2019). In recent years, the project portfolio model has become widespread. Example researches include the work of Szilágyi et al. (2020) in the oil and gas industry, Wu et al. (2019) in the field of energy, Hamidi Hesar Sorkh et al. (2021) in the pharmaceutical industry, Naji and Ali (2018) in the field of construction, Xu et al. (2021) in finance, and Arratia-Martinez et al. (2018) in the area of R&D.

Iran has numerous opportunities within the field of oil and gas. However, there are many limitations in this area. Iranian oil and gas production companies must allocate limited physical, human, and monetary resources for different projects. Incorrect decisions can generate insignificant income, negatively affect the national economy, and waste current limited resources (Karbasi Yazdi et al., 2020). Oil-producing countries are constantly looking for new fields, developing existing areas, and, generally, opportunities to increase project production (Pakdin Amiri, 2010). Since oil and gas resources are non-renewable and limited, the importance of planning for them increases. Optimal project planning is an essential issue in this industry because investment decisions in the oil and gas industry require a lot of capital (Huseby and Haavardsson, 2009).

Iran's upstream oil and gas industries are of considerable economic, political, and social importance. Technology sanctions, lack of foreign investment, reduced production and export of oil and gas, and, as a result, reduced revenues, which put the most constraint and pressure on the company's capital budget, have created challenging conditions for implementing plans and projects. This study identifies these projects in two categories: preservation of the fields' current production and development. Therefore, these companies must make the best of their limited resources. Thus, choosing the optimal project portfolio despite the limited resources to achieve the company's strategic goals is vital.

The main problem for oil and gas-producing companies is the limited budget for their capital projects. Meanwhile, there are different scenarios for intervention in upstream activities as capital projects. The scenario selection as a capital project for oil companies depends on its long-term impact on production and, as a result, the company's income. Therefore, what scenario oil and gas-producing companies should choose as a capital project in each field under budgetary constraints is essential. This will be the primary and vital question of this research, which will lead to the optimal portfolio of capital projects of oil and gas companies. Therefore, according to the features of mathematical modeling mentioned by Erzin et al. (2020) and Sohrabi (2021), this study aims to provide a model to determine the optimal portfolio of capital projects in upstream oil and gas companies. Because in the case of choosing an inappropriate project, in addition to losing the organization's resources, the organization's future opportunities are also at risk. A project is successful when it satisfies all the expectations when selected (Keshavarz Hadadha et al., 2018).

After reviewing the previous research in the field and stating the existing research gap, especially in Iran, this study uses the mathematical modeling method and exploratory analysis with an applied purpose. First, the necessary data for the oil and gas-producing company fields are obtained. After calculations, the parameters of the mathematical model are estimated. The introduced model is tested in one of the country's most important oil and gas companies as a case study. Finally, the findings and results will be explained as the optimal portfolio of the company's capital projects.

2. Theoretical background and literature review

Project portfolio management is the centralized management of plans and projects managed as a group to achieve strategic goals (PMI-Portfolio Management Standard, 2017). In other words, the organized management of all projects at the high level of organizations includes planning, scheduling, and designing projects, team management, and providing a collaborative environment to increase overall success (Bhatia et al., 2020). Therefore, there are three crucial goals for project portfolio management: Strategic alignment to ensure the strategic direction of projects, the balance between projects in terms of critical strategic components, including resources or risks, and maximizing the earned value in terms of company goals (Lappi et al., 2019). In general, it can be said that maximizing profits is the most fundamental and common strategic goal in defining the project portfolio. Moreover, various factors, such as project interdependency, project modification, project scheduling, resource allocation, and time horizons, are considered in selecting the most appropriate project portfolio (Zhong et al., 2019). With this definition, Iran's oil and gas-producing companies' portfolios will be related to their capital projects. Their capital projects directly affect their strategic goal of maintaining and increasing production and thus increasing revenue. In fact, from this point of view, the portfolio of oil and gas-producing companies consists of their capital projects.

According to the Institute for Project Management report in 2016, for every $1 billion invested in projects in the United States, poor project performance caused wasting $122 million. Therefore, the need to implement project portfolio management becomes more apparent. Also, as studies show, project portfolio management will align the company's projects with strategic goals and consequently increase profits (Sohrabi, 2021).

Researchers have used different methods to define the optimal project portfolio. For example, Salami et al. (2013) used the goal programming model, Barros de Oliveira et al. (2014) used the multi-objective genetic algorithm; Altuntas and Dereli (2015) applied the DEMATEL method, and Costantino et al. (2015) employed artificial neural network model; Ghafouri and Taghizadeh (2017) using firefly heuristic method and refrigeration simulation and Dong and Wan (2019) employing fuzzy multi-objective linear programming defined the optimal portfolio.

Other research in this area includes the study of Erzin et al. (2020), which provides a model using Markowitz's portfolio selection theory and zero–one integer planning modeling to support the strategic decision-making process. The results show that this model minimizes the investment portfolio's risk and provides the expected return. Using network analysis methods, Ho et al. (2011), DEMATEL and Vickor developed an investment decision-making model for optimal portfolio definition to obtain maximum profit upon the capital asset pricing model. In their research, Zolfagharo and Mousavi (2021) proposed a new model of mixed integer programming for portfolio selection and planning, considering resource management, cash flow, lag cost, and robustness of multiple projects. The results showed that the profitability of project-oriented companies depended on the proper portfolio selection, careful planning, and resource management.

In their research, Akhavan Tappesari et al. (2019) proposed a framework for selecting a portfolio in the oil refining industry. First, using a non-compensatory method with initial screening removes several inappropriate options, and with the help of a fuzzy hierarchical analysis process, they proceeded to rank the projects. Then, using the backpack model, they changed the coefficients of the objective function of each project in the model to preserve the projects' multi-criterion score and introduced the company's portfolio using integer linear programming. Using the multi-criteria decision-making model, Gama Lopes and Almeida (2015) evaluated oil and gas exploration and production projects in the development stage and selected the optimal portfolio.

Taklif et al. (2020) used a dynamic nonlinear optimization model to determine the optimal production level, maximize the project net present value (NPV), and define the portfolio in Phases 17 and 18 of the South Pars Gas Field. In this study, maximizing project NPV was considered the objective function, and the technical, technological, and contractual factors were considered model variables. The results showed that operations research programming models could be used to determine the level of oil production and develop master development plans (MDP). Mohagheghi et al. (2017), in their research, selecting R&D projects of an oil and gas development company, presented a new model that used the interval type-2 fuzzy sets (IT2FSs) to control uncertainty and semi-variance to assess risk. Therefore, risk and return were simultaneously considered in the selection process and helped select the optimal portfolio for the company.

Tang et al. (2017), with the help of the quadratic planning model and preference theory, proposed a method for re-optimizing the portfolio of oil projects under budget constraints and production capacity. Their results showed that cash flows and index rankings were inappropriate methods for project selection in declining oil fields. Flexible contracts improved optimization efficiency, reduced risk, and optimized budget allocation. Karbasi et al. (2020), in their research in an oil company under conditions of uncertainty, collected essential factors in the selection of oil projects by reviewing previous studies, interviewing experts, and filtering them using the Delphi method. Then, using the best-worst method, they prioritized the selected criteria. Quality criteria were the highest, and production technology had the lowest priority, indicating the impact of sanctions on oil production in Iran.

In the background study, no study comprehensively investigates the optimal portfolio of capital plans in the oil and gas-producing companies found. However, such a comprehensive study of the projects is essential due to the problematic conditions of financial resources and capital budget constraints in Iranian oil and gas companies because of political and economic conditions on the one hand and the need for operating, preserving, and increasing the production of current fields due to their long life.

This study first presents a mathematical model to define the optimal portfolio of capital projects in oil and gas and then develops its framework and process. Then, it applies the model to one of Iran’s largest oil and gas companies for the first time.

Table 1 demonstrates the most similar research in the literature review and the differences and distinctions of this study.

Table 1

Distinctions between the current study and the related literature (Source: Research findings)

Authors	Methodology	Results	Contribution
Gama Lopes and Almeida (2015) Altuntas and Dereli (2015) Mohagheghi et al. (2017) Mohagheghi and Mousavi (2021)	Using decision-making methods	Providing an integrated framework	Reliable results due to the investigation of all projects at the same time Paying more attention to the strategic goals of the company due to the systemic view
Akhavan Tappesari et al. (2019) Karbasi Yazdi et al. (2020) Taklif et al. (2020)	Investigating part of the company’s projects	Investigating all the company’s projects at the same time	Optimum use of the company’s resources by reviewing all the company’s plans Paying attention to the constraints related to the selection of projects instead of focusing only on predetermined criteria

Considering the decrease in foreign exchange and oil incomes that have affected the capital budget of these companies, the model presented in this study can be a suitable framework for studying the optimal portfolio of other oil and gas companies in the current situation. Also, the developed model can be used to analyze the optimal portfolio of capital plans for any similar company and adjust it according to its conditions.

3. Data and method

This research is applied in terms of purpose and case study in terms of research method. It is quantitative in terms of data type and the category of mathematical modeling in terms of data analysis method. This study aims to provide a model to determine the company’s optimal portfolio of capital projects by estimating and using the data related to 8 years between 2022 and 2029. Figure 1 shows the steps to develop the intended model, which is described along with other methodology sections. These steps were adjusted in two brainstorming meetings with an expert panel (company’s team of experts) led by researchers. Finally, with the facilitation of the research team, after numerous discussions, all experts agreed upon the model.

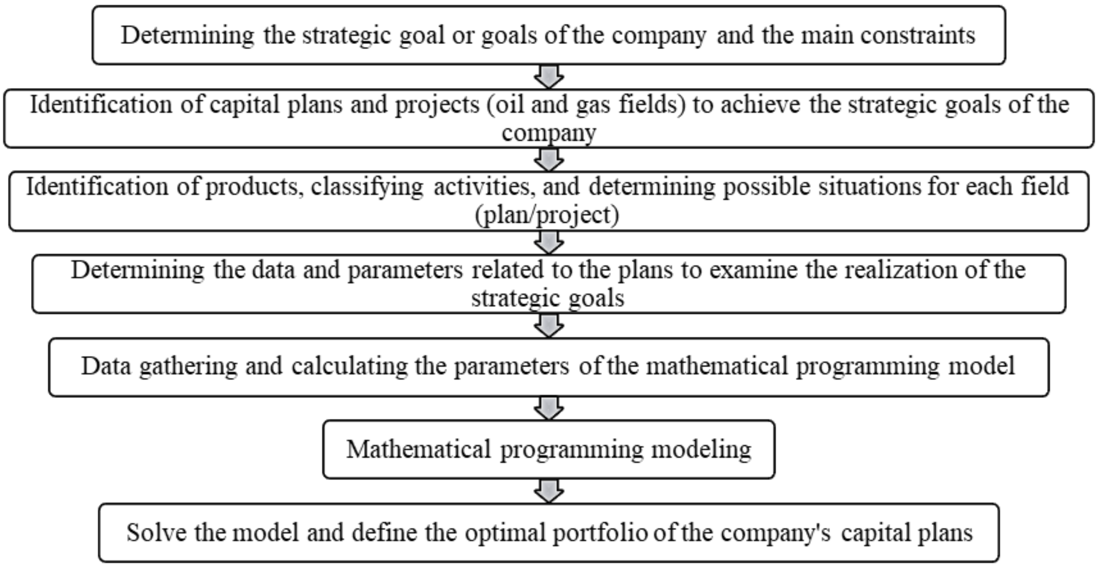

Figure 1

The flowchart of research method steps (Source: Research findings)

Step 1: With the help of strategic planning, the company's upstream documents, and the opinion of the company's senior management, the strategic goal of the company and main constraints were determined to set the optimal portfolio of capital plans.

Step 2: The company's oil and gas fields were identified, on which capital plans were defined. These fields were determined by meeting the expert panel formed for this study.

Step 3: During the expert panel meeting, each field's products and the different conditions that could be invested in each field were determined. At this stage, it was necessary to examine the main constraints of the study.

Step 4: The data and parameters required to review each company's capital plans with its various scenarios to achieve the strategic goal defined in the first stage were identified through a meeting with experts.

Step 5: After determining the required data type, using the researcher-made questionnaire, the necessary data for calculations were collected to estimate the parameters of the mathematical programming model.

Step 6: The calculations were performed to estimate the mathematical model's parameters, described in the following calculations, analysis method, and software used.

Step 7: The mathematical programming model of integers zero and one with the objective goal optimization function defined in the first stage was designed and developed.

Step 8: The designed model was coded and solved using GAMS software. Finally, according to the constraints defined in the third stage, the best investment scenario for each field was identified as the optimal portfolio of the company's capital plans.

The statistical population and the research sample are in two parts as follows:

1. Population related to all plans and projects of the company and associated data to estimate the parameters of the mathematical planning model.

2. Company experts (expert panel) accompanied during the research to prepare and verify technical and economic data. This team included managers and experts in the related departments, such as technical affairs management, engineering and construction management, and planning management. The team members were selected through snowball and judgmental sampling with the help of the company's CEO and senior management team.

4. Empirical results and discussion

The company studied in this research is one of the upstream companies in the oil and gas industry, which faces limited capital budgets like others. This constraint has created challenging conditions for implementing the company's plans and projects to preserve the fields' current status and development. Accordingly, company managers need a systematic framework for optimal management of the company's portfolio. Therefore, in the first stage, through meetings with the company's senior management and with the help of upstream documents in strategic planning, maximizing the NPV of the company's oil and gas production is identified as the company's strategic goal. This is required to be done by considering investment constraints.

Various methods for evaluating investment plans and projects are divided into discounting and non-discounting categories. Non-discounting methods can be called the accounting rate of return (ARR) and the payback period (PP). Due to not considering the value simultaneously, money is not a suitable criterion for long-term projects.

The internal rate of return (IRR) and the profitability index (PI) can be mentioned based on the net present value discount. The IRR is ineffective when facing unusual cash flows and in projects that are difficult to accumulate. Regarding the PI, it is impossible to add the amount obtained from different projects and use the final amount of all projects. NPV does not have any of these restrictions; thus, it is one of the most common approaches in defining the optimal portfolio of projects (Mohagheghi et al., 2019). Many studies have used it, so the calculations were made to estimate the NPV for all potential investment projects.

In the second phase of the research, 19 of the company's oil and gas fields were identified. Furthermore, different investment scenarios were determined for each of them through a meeting of experts. In discussion with experts, three modes were defined for each field. The first is to increase production through field development. The second scenario is the sustainability of production, and the third mode is the non-interference in the natural behavior of the reservoir, which allows the field to continue output based on its natural discharge rate according to the existing conditions. Identifying these three scenarios for each area was one of the most critical stages of modeling to determine the portfolio, which was not observed in any other research.

By identifying three scenarios for each oil and gas field, 57 projects could be defined. It was necessary to determine an optimal portfolio to realize the company's goals. Representing the optimal portfolio also involved determining and calculating model parameters and constraints. The most important limitation was budget and resources. Moreover, it was possible to choose only one of the three scenarios for each field based on this. According to the experts' consensus, it was decided to consider the net present value (NPV) of each scenario for each field as the productivity coefficients of the model. With detailed investigations of experts and discussions under the research team leader, it was found that the NPV calculation was sufficient for the production increase and maintenance scenarios. The third scenario (NDR) will be selected if none of these two modes are selected. Considering the impact of any investment on the behavior and production of the field in the coming years, the team of experts (expert panel) considered nine years to estimate the production and its costs for each oil and gas field. Following expert meetings (and the method of the subject matter expert), the required factors and data to calculate the NPV of each scenario's field will be mentioned. This process is the distinction of the study that was not observed in the literature review; however, it is considered an exploratory part of the research.

After formulating the zero–one integer programming model, each mode can be selected for the 19 specified oil and gas fields. Thus, in the mathematical model, two variables are considered for each area, representing two scenarios (mode) through the variable of "F_{ij}". These two variables are defined as "F_{ij}" (F_{i1} and F_{i2}), where *i* represents the field number and *j* represents the investment mode. As mentioned, *j* will be equal to 1 or 2. A *j* value of 1 means the field's best investment option is development operations, and a *j* value of 2 shows that performing sustainability of production operations will be the best option for that field. $F_{i1} = 1$ demonstrates the "development" scenario, and $F_{i2} = 1$ indicates the "sustainability of production" mode. It is clear that if $F_{ij} = 0$ suggests that "lack of investment and intervention in the natural behavior of the reservoir" should be the optimal option. According to these explanations, the mathematical programming model of integer zero consists of 38 decision variables and represents 57 investment modes. Table 2 lists the different modes of investment in the field according to the value of the *j* index.

Table 2

Different modes of investment in the field based on the value of *j* (Source: Research findings)

The value of the *j* index	The value of the variable	The scenario/mode of investment
1	$F_{i1} = 1$	Development
2	$F_{i2} = 1$	Sustainability of production

In the third step, it was necessary to determine the products of each field so that in the fourth step, based on it, the needed data to estimate the parameters of the mathematical programming model could be determined.

The fourth step was essential in determining the type of data. The parameters must first be defined at this stage so the research team can correctly define and select the data type. The parameters of the model include the following:

- The NPV of each investment mode for each field (corporate capital plans);
- The investment related to each mode;
- The annual budget constraint.

After determining the type of products of each field, a researcher-made questionnaire was designed to select the type of information required for each field. The data were related to the type and volume of production of each field and the amount of investment for each case ($j = 1$ or $j = 2$), which should be provided to the research team over eight years. The investment amounts according to the company's long-term plan were obtained through the review of planning management studies and were reviewed and finalized in the meeting of experts. For investment, the necessary foreign exchange and Rial costs were estimated. Preliminary production forecast figures were also obtained based on previous company studies and were verified by simulation in Petrel and Eclipse software. Therefore, the reliability of the obtained data was ensured by reviewing and retesting the data contained in the documents. To calculate the model parameters in addition to production and investment data, experts needed to agree on the following data:

- Crude oil prices;
- Rich gas price;
- Gas condensate price;

- Exchange rate;
- Discount rate;
- Rate of operating costs of each project;
- Rate of financing cost;
- Working days;

$$PV_{nj} = D_n * \left(\left(Price_{oil} * Product_{oil\,nj} \right) + \left(Price_{GC} * Product_{GC\,nj} \right) + \left(Price_{RG} * Product_{RG\,nj} \right) \right) \quad (1)$$

$$CF_{nj} = PV_{nj} - I_{nj} \quad (2)$$

$$NPV_j = \sum_{n=0}^{8} \frac{CF_{jn}}{(1+r)^n} \quad (3)$$

Specifying the income field and costs is necessary to estimate the NPV. Therefore, it is essential to determine the type of products in each field with the help of experts. According to experts, the production and investment interval are considered eight years due to the long-term effect of investments in production volume.

These were achieved during three meetings, each lasting at least 90 minutes, with the explanation and facilitation of the research team. Then, the NPV of each field was calculated in two modes of sustainability of production and production increase, as shown in Table 3.

Table 3

Coefficients of the objective function of mathematical planning model (MM$) (Source: Research findings)

Oil and gas field number	NPV in the sustainability of production mode	NPV in production increase
F1	378.3	1138.4
F2	330.2	413.1
F3	330.9	706.1
F4	293.4	2218.2
F5	3100.6	9408.8
F6	1791.7	5593
F7	957.8	4649.7
F8	–260.3	2669.3
F9	–297.2	–16.7
F10	958.8	3333.6
F11	394.5	542
F12	60.1	702.6
F13	223.7	969.8
F14	180.2	129.9
F15	351.3	664.8
F16	213.8	2422.4
F17	–340.9	1169
F18	793.6	206.4
F19	165.7	744.8

Table 4 also lists the required data to calculate the coefficients of the objective function (productivity coefficients) of the mathematical model. This table shows how to calculate a field.

Table 4

The data required to calculate the productivity coefficients (Source: Research findings)

Data Scenario	Unit	2021	2022	2023	2024	2025	2026	2027	2028	2029
Investment (2)	MM$	375.2	65.4	235.2	127.5	195.9	88.2	67.7	76	72.3
Investment (1)	MM$	190.9	26.2	94.4	51.1	78.6	88.2	67.7	76	72.3
Oil production (2)	MBBLD	99.4	96	95	90	105	105	105	76.4	66.3
Rich gas production (1)	MMSCMD	1.5	1.5	1.5	1.7	1.7	1.7	1.7	1.1	0.9
Gas condensate production (2)	MBBLD	0	0	0	0	0	0	0	4.8	4.2
Oil production (1)	MBBLD	57.9	47.9	38.9	30.9	23.8	17.5	12	7.1	2.8
Rich gas production (1)	MMSCMD	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0
Gas condensate production (1)	MBBLD	0.4	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.2
Product value (2)	MM$	2590.5	2496.6	2468.1	2349.1	2739.9	2349.1	2732.4	2106.8	1832.6
Product value (1)	MM$	1517.1	1252	1016.5	806.3	623.7	455.5	315	184.3	76.9
Cash flow (2)		2215.3	2431.2	2232.9	2221.3	2544	2644.1	2664.7	2030.8	1760.2
NPV (2)		11077								
Cash flow (1)		1326.1	1225.8	922.1	755.2	545.1	367.3	247.3	108.3	4.5
NPV (1)		3677.5								

It should be noted that the data in this table will be the objective function coefficients of the mathematical programming model of the problem. Another crucial data was the determination of the constraints of implementing plans and projects. This constraint was defined as “budget constraint” according to the conditions governing the country’s macroeconomy and the company and considering the urgency of problem-solving and access to data. Budget constraints, as the most essential and accessible constraint to solve the company’s problem, were decided in the meeting of experts. Finally, it was approved by senior management by presenting arguments. Then, considering the necessity of determining the “capital budget” of the following year, the “budget constraint” is defined, and along with other estimating parameters, the mathematical programming model of the zero–one integer was developed as described in Equation (2).

$$Max\ NPV = \sum_{j=1}^{2}\sum_{i=1}^{19} c_{ij}F_{ij} \tag{4}$$

$$\begin{pmatrix} F_{11} + F_{12} \\ \vdots \\ \vdots \\ F_{191} + F_{192} \end{pmatrix} \le 1 \tag{5}$$

$$\sum_{j=1}^{2}\sum_{i=1}^{19} a_{ij}F_{ij} \leq b \tag{6}$$

$F_{ij} = 0,1 \quad , \quad i = 1,2,3,\ldots,19 \quad , \quad j = 1,2$

Table (5) shows the parameters and variables of the mathematical model.

Table 5

Constructive parameters and variables of the mathematical model (Source: Research findings)

Parameters and variables	Description
n	The length of the study period based on an annual basis
j	Investment mode/scenario that can take the value of 1 or 2
D_n	Working days
GC	Gas condensate
RG	Rich gas
PV_{nj}	Product value
I_{nj}	Expenses and investments
i	The field number from 1 to 19
R	The project discount rate: its value is considered 15% based on what is accepted in the world oil and gas industry.
CF_{nj}	Company's cash flow
F_{ij}	The company's capital plans: oil and gas fields can take the value of 0 or 1
C_{ij}	Objective function coefficients: NPV of each field on each investment mode
a_{ij}	Technical coefficients of the problem constraints: the annual amount of investment of each scenario mode
b	The constraint of the company's annual capital budget

This model was coded and solved in GAMS software. Also, the first 19 constraints, the sum of the F_{ij} variables, guarantee the selection of one of three investment modes, including development, preserving or releasing the field, and production based on the natural rate of natural discharge.

The objective function of the mathematical model was to maximize the NPV of all oil and gas fields according to the investment options. The model's aim function consists of 38 decision variables in which the coefficient of each variable is the NPV for each investment mode in the company's oil and gas fields. The consequence of running the mathematical planning model in GAMS software includes determining the optimal scenario for each area and, finally, the optimal portfolio of the company.

Based on the constraints of the developed model, the optimal portfolio among 57 investment modes as scenarios includes 5 fields. The chosen scenario for three cases is production increase, and the two others are sustainability of production. Due to the main question and research problem mentioned in the introduction, not only was a model developed to achieve the optimal portfolio of capital projects, but also the result of the model implementation determined the optimal portfolio for this company. Unlike the current research, in previous research in the oil and gas field, there is often a partial view. The whole system as a whole is not included in this process, which causes the organization's strategy not to be comprehensively reviewed and provided, as can be observed in the works of Pakdin Amiri

(2010), Alinejad and Ghorbani Farahabadi (2014), and Karbasi Yazdi and colleagues (2020). Moreover, some research, such as Gamma Lopes and Almeida (2015) and Altontas and Darley (2015), rarely mentions financial indicators as essential. Nevertheless, in the current research and the research of Taklif et al. (2020) and Erzin et al. (2020), the optimal portfolio has been determined with more attention to financial criteria. The results show that data and financial indicators can provide reliable and better results. Conditions with financial and other characteristics, such as social, political, and environmental, can provide more comprehensive results.

5. Concluding remarks and policy recommendations

This study developed a mathematical model for determining the optimal portfolio of capital projects of one of the most important oil and gas companies. According to the implementation stages and comprehensiveness of this research, the introduced model can be used to define the optimal portfolio in other companies in the oil and gas industry. Further, the results of this study can be used to develop portfolio management knowledge and expand the current model and framework in oil and gas companies. Moreover, the developed model introduces a comprehensive framework for decision-making for the appropriate, balanced, and targeted allocation of resources, especially financial resources and budgets in different situations. The use of extensive financial and economic calculations, forecasting, and considering the variables effective on portfolio management in the long run and the model introduced to have a significant role in the applicability of the findings in the oil and gas industry and related industries.

The results of the implementation of the developed model show that due to the company's primary constraint, the capital budget constraint, the current investment strategies should be considered and reviewed in 14 of its 19 oil and gas fields due to lack of economic justification, Given the vital role of this company in the country's economy and national income, this result is also significant for the government and decision-making and policy-making institutions. The logical strategy in fields 14 and 18 is to carry out production maintenance operations, and in fields 5, 7, and 8, to carry out production increase operations through development, as presented in Table 6.

Table 6

Optimal investment portfolio (optimal portfolio) of the company (Source: Research findings)

Field number	Mode/scenario number	Mode/scenario
5	2	Production increase
7	2	Production increase
8	2	Production increase
14	1	Sustainability of production
18	1	Sustainability of production

An essential advantage of the proposed model is adjusting the optimal portfolio according to the long-term horizon, which is considered eight years in this study. Financial constraints are the most critical challenge for large industries, especially oil and gas industries in our country. The research results in Iran and the world show that implementing the portfolio management process causes optimal investment and increased income. Thus, it is recommended that the industries implement the model and framework mentioned in this study to optimally invest resources in plans and projects, leading to more excellent value and profit. It should be noted that project portfolio management is an ongoing process. According to changes in data and forecasts, information should be updated for future years to determine the exact results and suitable strategies for each year.

Nomenclature

ARR	Accounting rate of return
CEO	Chief executive officer
CF	Cash flow
DEMATEL	Decision making trial and evaluation laboratory
F	Field
GAMS	The general algebraic modeling system
GC	Gas condensate
IRR	Internal rate of return
IT2FSs	Interval type-2 fuzzy sets
MBBLD	Thousand barrel per day
MDP	Master/main development plan
MM$	Million dollar
MMSCMD	Million standard cubic meter per day
NDR	Natural decline rate
NPV	Net present value
PI	Profitability index
PMI	Project management institute
PP	Payback period
PV	Present value
R&D	Research and development
RG	Rich gas

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