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Designing an Investment Policy Analysis Model for Oil Production Using System Dynamics Method

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A B S T R A C T

Objective: The objective of this research was to design a model for analyzing investment policies in oil production using content analysis and the Delphi method and the system dynamics method.

Methodology: The statistical population for content analysis included upstream documents of the oil industry and articles related to investment in oil production available on the Ministry of Oil's website and a comprehensive article database, amounting to 29 articles related to investment in the oil industry. Based on the acquisition method, 9 articles were selected for content analysis. In the Delphi section, officials, managers, and deputies of this company, along with university professors in public administration in Khuzestan province, totaling 32 individuals, were included in the statistical population, and 15 individuals were selected as the statistical sample using a purposive stratified method. In the quantitative section, the statistical population included all employees, managers, official experts, and employed personnel of the National Iranian South Oil Company in Ahvaz, totaling 570 individuals. Using the simple sampling method and based on Cochran's formula and random method, 291 individuals were calculated as the statistical sample.

Findings: After confirming the dimensions and components in the Delphi system dynamics section using Vensim software, 9 scenarios were considered: 1- Reduction of unfavorable monetary policies, 2- Improvement of financial assessments, 3- Improvement of investment source diversity, 4- Structural development of oil extraction and production, 5- Improvement of research and development policies in the oil industry, 6- Improvement of financing based on underground reserves, 7- Improvement of debt-based financing, 8- Improvement of intermediary financing, 9- Improvement of policies for the introduction of oil technologies.

Conclusion: Therefore, in this loop, the assumption is that potential risks affect monetary policies, financial assessment, and investment management. Investment management reduces socio-cultural factors, and when socio-cultural

factors decrease, it increases environmental neglect. The more environmental neglect increases, the production ceiling in the oil industry is likely to decrease. These factors ultimately cause the tendency to weaken investment policies in oil production.

Keywords: *Investment, Oil Industry, Dimensions, Systemic Approach, System Dynamics, Causal Loop Model*

1 Introduction

Investments in various fields have always been considered one of the important ways to develop companies (Momenirad & Yousefi, 2023; Nasirzadeh et al., 2021). Investment opportunities available to companies form a significant part of a company's value. The emergence and expansion of young companies in the field of information technology and the global economic conditions have sparked great interest in understanding the role of such investment opportunities in companies (Rasoul et al., 2023; Tayebeh et al., 2019). Cash is one of the most critical needs of any unit to carry out activities, as it can impact various factors and ultimately increase the company's activities and generate returns for shareholders (Pourghaffar & Ghaderzadeh Oskoee, 2021).

Long-term investments significantly impact the growth and development of a country's or region's oil industry. Generally, one of the main drivers for increasing investments in the oil sector is ensuring demand security. Additionally, economic considerations, along with other factors such as political issues, international support, and geographical constraints, play an important role in this process (Vedadi Kalantar, 2016).

Iran, with its vast oil and gas reserves, possesses a strategic advantage in valuable natural resources. With approximately 157.8 billion barrels of proven oil reserves (9.1% of the world's proven crude oil reserves), Iran ranks second among the Commonwealth of Independent States (CIS) countries and first in the CIS with 32.1 trillion cubic meters of natural gas reserves (17.1% of the world's proven gas reserves) (Corrales et al., 2020; Hosseini et al., 2021; Okoro et al., 2021). Countries like Iran with vast oil resources experience significant economic mobility directly influenced by the performance of the oil sector in exports or domestic energy supply, affecting economic prosperity or recession. Given Iran's high revenue from the oil sector and the government's budget dependency on these revenues, oil prices and daily production are crucial, and managers in Iran's oil sector must pay more attention to production in Iran (Rajabian et al., 2020). In the production sector, attention must be given to Iran's reservoirs, OPEC quotas, the age of oil fields, efficiency, technology, and infrastructure. Oil production should match production capacity, which increases with investment and decreases with declining oil fields and infrastructure (Hosseini et al., 2021; Rajabian et al., 2020).

In recent decades, the lack of impactful roles in domestic and international markets has directly reflected the positive and negative effects of the oil market on economic fluctuations. For years, the country's economy, due to the structural weakness of the capital market and the lack of parallel progress in downstream industries, has been unable to be independent of fossil resources (Hosseini et al., 2020). Investment is considered one of the most vital factors to encourage all economic and social systems towards development (Akbari & Mehrjerdi, 2011; Rajabian et al., 2020). Optimal attraction and allocation of necessary investment in various sectors pave the way for sustainable development. The importance of this point in Iran's oil industry is doubled due to the general policies of Article 44 of the Constitution, which largely dedicated the oil industry to the government. Therefore, the government has not allowed direct access to investment in upstream (oil extraction) and downstream (petrochemical complexes construction) oil industries. Thus, proper policies and the creation of necessary infrastructures should be implemented to attract private sector and foreign investments (Hosseini et al., 2021; Hosseini et al., 2014; Niazimohseni et al., 2020).

The problem can be articulated in this research as follows: Nowadays, monetary and financial dependency on the oil sector in Iran (as one of the oil-exporting countries) has made monetary policies a major challenge for economic policymakers (Niazimohseni et al., 2020). In the oil industry, due to the lack of a sustainable platform at the strategic level and the creation of a market-oriented and international business environment and interaction with investor countries in the oil sector, it has been shown that a reliable and stable market in the field of energy and oil trade has not been achieved. Furthermore, existing problems and issues in a significant part of the oil industry's investment needs related to purchasing and supplying goods, in addition to using

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domestic capabilities, have prevented proper investment in this sector due to sanctions in recent years.

Using the system dynamics model, better understanding of the interactions between oil and gas industry factors can be achieved, improving investment decisions and productivity in oil and gas production. This model can also help managers and policymakers in the oil and gas industry to determine better strategies for achieving economic, social, and environmental goals. This research aims to develop a reliable model for investment in Iran's oil and gas industry using the system dynamics method for the first time. This model is expected to serve as an investment pattern in the oil and gas sector, but it should be noted that it is applicable under specific conditions for each country. The system dynamics model, which adjusts the investment process in the oil and gas industry dynamically according to current and future conditions, can significantly improve the performance of the oil and gas industry. This model functions by prompting investors to make efforts based on changes in the market, technology, government policies, and other factors. Therefore, this model is unique and innovative for each country's specific conditions and has not been implemented in Iran yet. This research aims to address the mentioned research gaps and, from this perspective, is essential and necessary. Given that the national interests of countries with rich oil resources, like Iran, are tied to these resources, these countries strive to make their financial regime and licensing system as attractive as possible for oil investors. Conversely, due to uncertainties and risks in exploration and production activities, decision-making for investment in upstream projects has always been challenging for investors. Therefore, a low-risk model is needed so that investors can estimate the expected financial outcomes of upstream projects and adjust themselves to maximize profits and benefits. Based on the above points, the main question of this research is: What is the investment policy analysis model for oil production using the system dynamics method?

2 Methods and Materials

In this research, the applied research method is used. This method is used to design an investment policy analysis model for oil production using the system dynamics method. This model, derived from content analysis and the Delphi method, is implemented with the system dynamics method. A model that has not been previously presented by other researchers in this field, hence, this research is applied based on the used resources.

Given that this research aims to design an investment policy analysis model for oil production using the system dynamics method, the Saunders et al. (2016) research onion model is used to explain the research layers from philosophy to technique. The advantage of using this model is providing a cohesive and consistent understanding of the conducted research.

For analyzing economic processes, simulation model development is based on specific environments being created and is in progress. Currently, common environments for developing simulation models like Stella (Ithink), Anylogic, Vensim, and Powersim are known. These not only allow for the rapid creation of simulation models using simple visual tools but also enable the analysis of created model functions and use these models to evaluate the impact of management decisions on economic process trends in modeled systems.

The dynamic system design model can be illustrated as shown below. The model elements and relationships between them define the model structure. System dynamics is based on feedback theory and integrates topics like information theory, management science, and decision theory. With principles defining system functions, the entire system can be modeled as a graph structure and its functional relationships. Then, a feedback loop with feedback control theory is created. Finally, the system dynamics model is developed and modeled using a computer. The oil company operates in the exploration, development, and production of oil and gas.

In other words, exploratory analysis can structure, model, or hypothesize beyond exploratory or propositional value. Exploratory analysis is considered more of a theory-formulating method rather than a theory-testing method. After exploratory factor analysis, final explorations for selecting the correct indicators for each factor were conducted, and for data input into Vensim software, several indicators with low factor loadings or unrelated to the intended variable were selected.

In the content analysis section, the statistical population of this research included upstream documents of the oil industry and articles related to investment in oil production available on the Ministry of Oil's website and comprehensive article databases like Noormags, IranDoc, Civilica, Magiran, and Sika, where 29 articles related to investment in the oil industry were found. After initial reviews and examination of the articles' content, abstracts, topics, and contents, sampling was conducted as follows.

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To ensure the validity of results with specific qualitative research criteria, necessary reviews, including acceptability (expert review methods) and confirmability (using experts for review and confirmation), were conducted. To achieve this goal, the seven-step method of Sandelowski and Barroso (2003, 2007) was used. Finally, the remaining articles moved to the next step. The total number of final articles in this research is 29. The selected sample articles were reduced to 9 and formed the basis for qualitative content analysis, in addition to upstream oil and gas documents.

Based on the geographical classification, the National Iranian South Oil Company - Ahvaz was selected, and the headquarters of this company was chosen as the statistical population. Officials, managers, and deputies of this company, along with university professors in public administration in Khuzestan province, were selected as the statistical population, totaling 32 individuals, and 15 were chosen as the statistical sample using a purposive stratified method.

In the quantitative section, the statistical population of this research included all employees, managers, and official and employed experts of the National Iranian South Oil Company - Ahvaz, totaling 570 individuals. Using a simple sampling method and based on Cochran's formula and random method, 291 individuals were calculated as the statistical sample.

Descriptive and inferential statistics methods were used to analyze the data. Additionally, SPSS and Vensim software were used for data analysis. The quantitative phase of this research involves using statistical data and methods to model and forecast investment in the oil and gas industry. In this phase, system dynamics analysis, mathematical modeling, and sensitivity analysis are used to examine the impact of various factors on investment. The goal of this phase is to determine investment strategies in the oil and gas industry considering current market conditions and future changes.

Variables for modeling the problem:

- Variables of the problem
- Extracted from the Delphi method

Finally, the collected data were analyzed using Vensim software.

3 Findings and Results

In the qualitative content analysis, 88 indicators and 13 components were identified. These factors were used for the Delphi method.

After identifying the initial components of investment policies in oil production through qualitative content analysis, for qualitative validation and screening of the identified components, 15 deputy managers, directors, and professors in management and investment from the oil industry were selected as panel members for the Delphi method to evaluate the validity of the components. The Delphi method was implemented in two rounds, reaching theoretical saturation in the second round. In the first round, 88 components participated in the Delphi process, and feedback was collected. The Kendall's coefficient of concordance was calculated, and the following results were obtained. To express the agreement among the Delphi panel, Kendall's coefficient of concordance was used. This value is 0.504, indicating that almost fifty percent of the experts agree. Therefore, complete consensus was not achieved Given that the Delphi questionnaire used a 5-point Likert scale, with the highest score for each variable being 5 and the lowest score being 1, the acceptance criterion for variables in each round of the questionnaire was a statistical average of 4 and above. Variables with a statistical average higher than 4 were considered as outputs of the first-round Delphi questionnaire. By eliminating variables with an average of less than or equal to 4, the remaining variables are listed. Considering:

a- In the group of social outcomes, all components, i.e., sustainable income, reduction of environmental risks, increased employment levels, increased political stability, technology development, increased bargaining power in oil markets, supply management in the oil market, oil resource development, and fintech development in oil,

b- In the group of political factors, components such as the government's economic preference for freedom, unjustified economic projects, the time to achieve economic-political project results,

c- In the group of investment policies, components such as policies for the development of shared infrastructure, policies for supporting domestic production,

d- In the group of technological factors, components such as sanctions, technology transfer, labor employment boom,

e- In the group of investment characteristics, components such as the need for domestic investors, unplanned liquidity circulation in the national economy, directing domestic investment towards the oil industry, lack of budget for oil company financing projects, and the need for foreign

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investors, had an average of less than 4, they were removed in the second round of Delphi. These changes were surveyed among experts in the second round of Delphi. Sixty-three components were approved by experts, but consensus was not achieved. Therefore, we will enter the second round of Delphi (Table 1).

Table 1

Components Removed in the First Round of the Delphi Method

Sub-group	Removed Components	Reason for Removal
Social Outcomes	Sustainable income, reduction of environmental risks, increased employment levels, increased political stability, technology development, increased bargaining power in oil markets, supply management in the oil market, oil resource development, fintech development in oil	Average less than 4 in the first round of Delphi
Political Factors	Government's economic preference for freedom, unjustified economic projects, time to achieve economic-political project results, laws and regulations for investment path, project costs, outdated technology and innovations	Average less than 4 in the first round of Delphi
Investment Policies	Policies for the development of shared infrastructure, policies for supporting domestic production	Average less than 4 in the first round of Delphi
Technological Factors	Sanctions, technology transfer, labor employment boom	Average less than 4 in the first round of Delphi
Investment Characteristics	Need for domestic investors, unplanned liquidity circulation in the national economy, directing domestic investment towards the oil industry, lack of budget for oil company financing projects, need for foreign investors	Average less than 4 in the first round of Delphi

In the second-round questionnaire, with the removal of components that had an average of less than 4, 63 components remained in the Delphi round. The second-round questionnaire was revised and delivered to the experts. Sixty-three components were approved, and Kendall's coefficient of concordance in the second round was 0.711. Therefore, overall agreement and consensus were achieved.

Given that all variables obtained an average above four and Kendall's coefficient of concordance was also above 0.6, the Delphi rounds were stopped, achieving theoretical saturation among the experts. The final output of the second round of Delphi is as follows. Based on the high Kendall's coefficient and the average above 4 for all research components, theoretical saturation among the experts was achieved, the Delphi rounds were stopped, and data stability was reached. Therefore, for entering dynamic planning and policy analysis and creating investment policy scenarios for oil production, the following classifications were made (Table 2).

Table 2

Classification of Policies and Creation of Investment Policy Scenarios for Oil Production

No.	Dimension Name	Component Name	Number of Components
1	Political Factors	Investment policy, negative public perception towards investment and foreign investment, existence of monopolies and political rent, adverse view of political and economic decision-makers towards investors, complex bureaucracy	5
2	Investment Policies	Policies: R&D in the oil industry, direct foreign investment, introduction of oil technologies, diversification of investment sources, development of oil extraction and production structures	5
3	Upstream Resources	Debt-based financing, intermediary financing, equity-based financing, financing based on underground reserves, production-based repayment financing	5
4	Technological Factors	Qualitative aspect of investment, increased profit from optimized oil production, productivity and optimization of oil production, attractiveness of the oil industry for foreign investment	4
5	Investment Characteristics	Investment through new oil contracts (IPC), efforts for economic management	2
6	Reducing Factors	Potential risks, environment, production ceiling, monetary policies, financial assessment, socio-cultural, investment management	7

Once the problem is identified and specified over an appropriate time horizon, modelers should begin to formulate a theory known as a dynamic hypothesis to explain the behavior of the problem. In the modeling process, it is customary to introduce the related dynamics for the problem variables. Based on the desired dynamics in the

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system of investment policies in oil production, they are considered as follows:

- Dynamics due to political factors
- Dynamics due to investment policies
- Dynamics due to upstream resource financing
- Dynamics due to technological factors
- Dynamics due to investment characteristics
- Selecting the Most Attractive Scenario

In Table 3, the nine scenarios examined are presented, with results in the preferred state and scenario, as well as the increase in units. The three scenarios with the highest increase were chosen as the most attractive scenarios.

Table 3

Nine Scenarios in Preferred State and Scenario, as well as Increase in Units

Scenario	Reference	Scenario Result	Final Result
Scenario 1: Reduction of unfavorable monetary policies	68.7324	106.408	(Increase of 37.6756 units)
Scenario 2: Improvement of financial assessment	68.72	121.553	(Increase of 52.529 units)
Scenario 3: Improvement of investment source diversity	68.72	118.89	(Increase of 50.17 units)
Scenario 4: Improvement and development of oil extraction and production structures	68.72	78.7361	(Increase of 10.0121 units)
Scenario 5: R&D policies in the oil industry	68.72	100.537	(Increase of 31.813 units)
Scenario 6: Financing based on underground reserves	68.72	138.313	(Increase of 69.589 units)
Scenario 7: Debt-based financing	68.72	177.066	(Increase of 108.642 units)
Scenario 8: Intermediary financing	68.72	197.587	(Increase of 128.863 units)
Scenario 9: Improvement of oil technology introduction policies	68.72	81.4618	(Increase of 34.7378 units)

Based on the above, the most attractive scenarios can be considered as follows:

a) Most Attractive Scenario 1: Intermediary financing (Increase of 128.863 units)

b) Most Attractive Scenario 2: Debt-based financing (Increase of 108.642 units)

c) Most Attractive Scenario 3: Financing based on underground reserves (Increase of 69.589 units)

4 Discussion and Conclusion

The investment policy analysis model for oil production using the system dynamics method, designed with Vensim software, identified dimensions and components initially through the content analysis of upstream documents of the oil industry and investment articles in this industry.

After analyzing the content of upstream oil industry documents and existing articles in this field, the dimensions of the investment policy analysis model for oil production were identified as follows: Environment, political factors, investment policies, potential risks, upstream resource financing, production ceiling, socio-cultural, technological factors, and investment characteristics. After analyzing the content of upstream oil industry documents and existing articles in this field, the components of each dimension of the investment policy analysis model for oil production were identified as follows:

a) Environment: Environmental laws, environmental standards, pollution levels related to oil-rich areas, local and international environmental commitments and agreements.

b) Political Factors: Investment policy, negative public perception towards investment and foreign investment, existence of monopolies and political rent, adverse view of political and economic decision-makers towards investors, complex bureaucracy.

c) Investment Policies: Policies for R&D in the oil industry, direct foreign investment policies, policies for introducing oil technologies, policies for diversifying investment sources, policies for developing oil extraction and production structures.

d) Upstream Resource Financing: Debt-based financing, intermediary financing, equity-based financing, financing based on underground reserves, production-based repayment financing.

e) Potential Risks: International sanctions, dependence of oil industries on foreign investment, lack of social support, lack of support from government and ruling sectors, security risks, oil price fluctuations.

f) Socio-cultural: Collaboration with local communities, investment culture in the country, local development in oil fields, local values and beliefs related to investment, public media support for oil investment.

g) Production Ceiling: Global oil prices, revenues, amount of domestic investment, domestic and global oil demand, amount of domestic and foreign investment, remaining discovered resources, type of exploration, level of exploratory activities, percentage of discoverable resources, percentage of producible reserves, proven and recoverable

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reserves, production rate, R/P ratio, percentage of capacity utilization.

h) Technological Factors: Attractiveness of the oil industry for foreign investment, increased profit from optimized oil production, productivity and optimization of oil production, qualitative aspect of investment.

i) Investment Characteristics: Investment through new oil contracts (IPC), efforts for economic management.

j) Monetary Policies: Interest rates on oil-related banking facilities, oil-related legal reserves rate, inflation rate, economic growth rate.

k) Investment Management: Description of investment criteria and scenarios, investment results, incremental net flows, sensitivity analysis.

l) Financial Assessment: Government financial resources, type of foreign investment, self-popular investment, bank-controlled investment, financial guarantor of the National Development Fund.

3. Reinforcing and Weakening Loops of the Investment Policy Analysis Model for Oil Production Using the System Dynamics Method

The system dynamics method for the investment policy analysis model for oil production showed that two main reinforcing and weakening loops exist as follows:

a) Reinforcing loops include political factors, investment policies, upstream resource financing, technological factors, and investment characteristics.

b) Weakening loops include potential risks, environment, production ceiling, monetary policies, financial assessment, socio-cultural, and investment management. Weakness in any of the above factors will lead to weakening the obtained policies. In this loop, the assumption is that investment policies in oil production are reinforced by some factors and weakened by others. Therefore, in this loop, the assumption is that potential risks affect monetary policies, financial assessment, and investment management. Investment management reduces socio-cultural factors, and when socio-cultural factors decrease, it increases environmental neglect. The more environmental neglect increases, the production ceiling in the oil industry is likely to decrease. These factors ultimately cause the tendency to weaken investment policies in oil production.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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