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Identification and Prioritization of Challenges and Development Technologies in One of Iran's Oil Fields in a Well-based Approach

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ABSTRACT

The development and production of oil and gas reservoirs in Iran, possessing one of the largest oil reserves globally, face significant challenges. To address these challenges effectively, this paper employs modern techniques, including the Technology Tree and Morin Model, to identify and prioritize the challenges and solutions for the technological advancement of an Iranian oil field. Through collaboration with experts, target technology areas and oil field challenges are identified, and their priority is determined using the Morin Model. Key technologies in these areas are identified through questionnaires and expert consultations. Challenges such as advanced drilling techniques, enhanced oil recovery methods, and efficient reservoir management are highlighted, with prioritization crucial for resource allocation. The study focuses on south Iran, primarily examining the period from the late 1960s to the present day, with a particular emphasis on reservoir and well behavior, especially within the Ilam formation. A multidisciplinary expert committee, including representatives from the National Iranian Oil Company, Amirkabir University of Technology, and Iran Offshore Oil Company, oversaw the research. The validation of results was conducted through questionnaires and interviews, resulting in the development of a roadmap for oil field technologies in collaboration with relevant experts. Key technological solutions include improving drilling methods, utilizing downhole sensors, hydraulic fracturing, acidizing, and deploying smart systems in producing wells. This comprehensive framework emphasizes collaboration, validation, and prioritization in addressing technological challenges in Iran's oil industry, ensuring practical and effective solutions.

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Introduction

Increasing the lifespan of oil reservoirs and improving production requires the use of appropriate methods. In the production phase, improving oil recovery requires addressing and optimizing the three main components of the reservoir, well, and surface facilities [1].

Improvement methods can be reservoir-based, well-based, or facility-based. Reservoir-based methods face challenges such as the lack of comprehensive information about the entire reservoir for more accurate decision-making, the need for extensive geological and geophysical information, and the need for water and gas resources for enhanced recovery operations and increased production, alongside high costs and longtime requirements [2].

Given the limitations of reservoir-based methods, the use of well-based methods can lead to increased production in a shorter time and with lower costs. In these methods, reactive and proactive approaches are used to improve performance. Given the advantages that well-based methods bring, more effective, efficient, and economical oil production can be achieved in current economic conditions. Therefore, the use of well-based methods can be suitable and optimal for improving oil production efficiency [1, 2].

The development of well-based technologies in the Iranian oil industry is one of the most important factors affecting productivity and production in the oil industry. Improving extraction and oil production methods and technologies has a significant impact on the growth and progress of the oil industry. The importance of developing well-based technologies in exploiting oil reserves can be examined from several perspectives. By employing well-based technologies, well performance and efficiency increase. In addition to increasing production, costs decrease, and operations improve. The use of well-based technologies is an effective solution for reducing errors and problems in well operations [2, 3].

Developing a technology roadmap for identifying and prioritizing challenges and solutions for well-based technology development is very important. This technology roadmap plays an important role as a strategic framework and operational direction in improving and optimizing the development of well-based technologies in Iranian oil fields. Developing a technology roadmap helps to accurately identify existing challenges in the field of well-based technologies and, by collecting the necessary data and information, enables the most accurate identification of challenges. Additionally, prioritizing challenges can prioritize requirements. Developing a technology roadmap can also optimize the resources and facilities required to implement solutions and, by developing comprehensive and targeted strategies, provide the possibility of strategic direction in the development of well-based technologies [3, 4].

Fig. 1 illustrates the importance of developing well-based technologies and technology roadmap development.

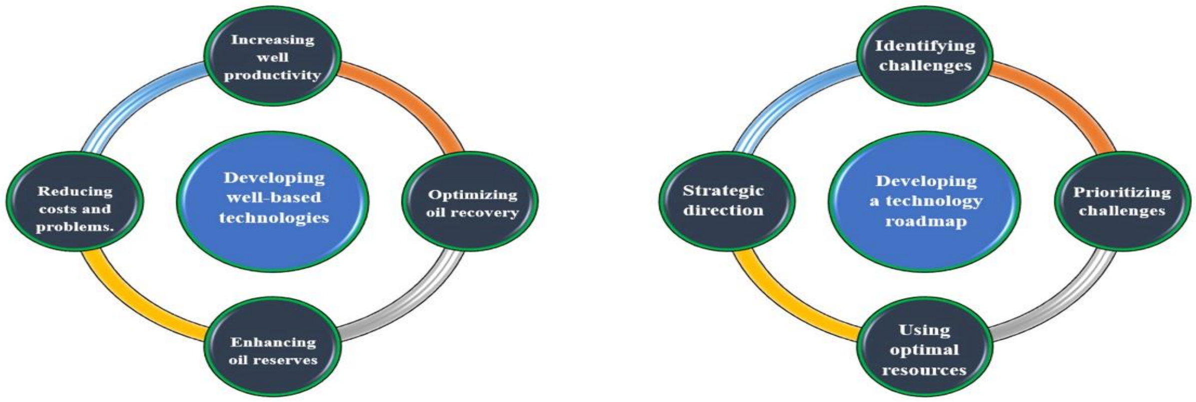

Fig. 1 Importance of developing well-based technologies and formulating a technology roadmap [3,4]

Creating a comprehensive technology roadmap in the field of petroleum engineering can be represented in Fig. 1. This roadmap includes elements such as: enhancing well productivity, optimizing oil recovery, decreasing costs and challenges, and augmenting oil reserves. This roadmap aids in:

1. Identifying challenges.
2. Prioritizing challenges.
3. Setting strategic directions.
4. Efficiently using available resources.

By following this roadmap, the industry can achieve improved well performance, increased oil recovery rates, reduced costs, and enhanced oil reserves, ultimately leading to overall operational efficiency and profitability.

Iran has the lowest number of completed wells based on hydrocarbon reserves among OPEC countries, in addition around 35% of drilled wells in Iran are inactive. The main reasons for the operational closure of oil wells in Iran are excessive water production, well problems, and low pressure inside the wells. The rate of depletion of oil reservoirs in Iran is 0.8% [5]. Addressing production challenges, improving production, reviving low-yield and inactive wells using appropriate methods such as well-centered methods, and setting the right priorities will be possible. Therefore, this article focuses on identifying and prioritizing challenges and development technologies in one of Iran's oil fields in a well-centered manner [6].

Research Background

Review of Research in Iran and Other Countries on Identifying and Prioritizing Technological Solutions

Table 1 presents studies conducted in Iran and various countries. Various studies conducted in different countries such as Iran, Norway, Canada, Oman, Qatar, Saudi Arabia, the United States, and Russia focus on analyzing and addressing challenges related to the oil industry through different methodologies.

Table 1. A review of studies conducted in Iran and various countries on the identification and prioritization of technological solutions.

Country	Type of Study	Name of Researcher or Institution	Prioritization Method	Oil-related Challenge
Iran	Policy analysis and production improvement	National Iranian Oil Company 2021 [7]	Value Chain Approach (VCA)	Fluctuations in global oil prices, low productivity coefficient
	Advanced research	University professors 2020 [8]	Technology tree (TT)	Technology gap in drilling and extraction
	Technology development analysis	Energy company researchers 2019 [9]	Quality Function Deployment (QFD)	Problems in well operation, challenges in production system failures
	Scientific research	Oil project engineers 2018 [10,11]	Morin model	Reduced well productivity, reservoir damage, waste of completion fluids
Norway	Policy analysis	Energy Researcher 2020 [12]	Technology tree (TT)	Technology gap in drilling and extraction, changes in global oil demand and supply, reduced recovery coefficient
Canada	Comparative study	Oil project manager 2019 [13]	Morin model	Reduced oil production

Oman	Advanced research	University Professors 2021 [14]	Quality Function Deployment (QFD)	Problems in well operation
Qatar	Policy analysis	Oil and gas company CEO 2018 [15]	Value Chain Approach (VCA)	Dependency on oil resources
Saudi Arabia	Policy analysis	Energy consultant 2020 [16]	Value Chain Approach (VCA)	Fluctuations in global oil prices, need for advanced extraction
United States	Case study	Energy researcher 2021 [17]	Quality Function Deployment (QFD)	Competition with large global companies
Russia	Scientific research	Oil project engineers 2018 [18]	Morin model	Financial problems due to oil price fluctuations, and production obstacles such as flow assurance issues.

Literature in express

Technology strategy encompasses the choices made by companies regarding investments in various areas such as research and development for new products, enhancement of existing processes, integration of innovative digital solutions, and advancement of their technologies. These decisions are influenced by the overall strategic direction of the company, guiding priorities for technology investments. By serving as both an operational roadmap and a competitive tool, technology strategy plays a crucial role in driving organizational growth and achieving strategic objectives through continuous technological development.

In strategic technology management, the initial step involves crafting a comprehensive long-term plan known as a technology strategy. This strategy serves as a blueprint for determining investment priorities and addresses key questions such as securing sustainable competitive advantage, managing access to technology, identifying suitable ways to acquire technology, and leveraging technological assets and capabilities effectively [19].

Focusing on the selection of activities to allocate public resources, and prioritize science and technology plays a crucial role in enhancing the return on government investments in research and aligning them with the long-term socio-economic objectives of a nation. This approach brings the attention of policymakers and investors to making strategic investments in science and technology. Within the framework of developing a technology strategy, this concept outlines the implicit prioritization of technologies. To prioritize technologies effectively, two key evaluations need to be conducted concurrently: an assessment of the desirability of the technology, considering global and social trends, and an evaluation of its feasibility, including research and development potential, production capabilities, and the likelihood of successful adoption and utilization [20, 21].

To identify technological solutions, the following models presented in Table 2 are usually used.

Research Methodology

To identify technological solutions in the Iranian oil fields with a focus on addressing challenges in a well-based manner, the research team decided to use the technology tree method for identifying and the Morin model for prioritizing technological solutions, based on the characteristics of this research project and analysis of documents, international and domestic articles and reports, as well as interviews with experts [24]. The stages of this methodology are presented in Fig. 2.

Table 2. Models for identifying and prioritizing technological solutions.

Technology Identification [22]	**Technology Prioritization [23]**
Technology Tree: This method represents the relationships between technologies and products or services in a hierarchical manner. This method has advantages such as ease of use and explaining the relationships between technologies and products. However, this method cannot comprehensively and in detail analyze the relationships between technologies and products.	Morin Model: In this method, technological solutions are improved and optimized for identified problems using system analysis. This method has advantages such as comprehensive and systematic examination, improving efficiency, and reducing costs. However, this method requires expertise and technical knowledge and may face operational problems.
Quality Function Deployment (QFD) Model: This method identifies customer needs through surveys and priority analysis and ultimately provides technological solutions. This method has advantages such as focusing on customer needs, increasing customer satisfaction, and reducing product errors. However, this method is time-consuming and costly and requires expertise and technical knowledge.	Analytic Hierarchy Process (AHP): This model is used to prioritize multiple options against multiple criteria. In this model, criteria and options are hierarchically related to each other, and final priorities are determined for each option.
Value Chain Analysis (VCA): In this method, each stage of the production chain is analyzed and optimized separately from the beginning to the end. This method has advantages such as improving quality and reducing costs, increasing profitability, and competitiveness. However, this method requires more resources and time and may face operational problems in some cases.	Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): In this model, options are ranked based on their distance from an ideal state. The ideal state is usually defined as a set of desired criteria.

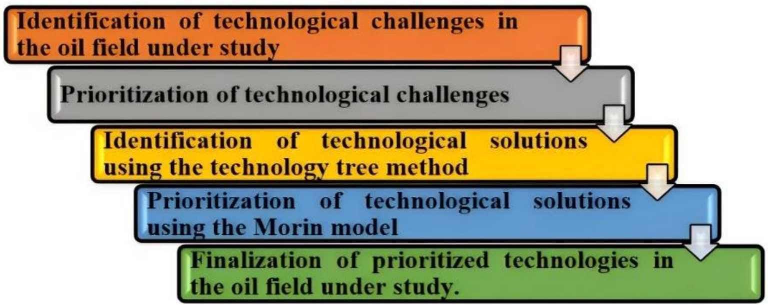

Fig. 2. Research Methodology Steps

Identification of Technological Challenges in the Oil Field under Study

By conducting field studies and reviewing the production history of the oil field under study, the challenges of this field were divided into two categories: challenges related to reservoir behavior and challenges related to well behavior. Challenges related to well behavior also include two subgroups of inflow and outflow performances. An example of production history charts for the studied field is shown in Fig. 3.

Fig. 3 shows the field's oil, gas, and water production profile. As can be seen, field water cut is insignificant and therefore it is not a history-matching parameter.

At its peak, the field produced 19,300STBD in late 2000-early 2001 through 11 producers but it could not be sustained. The cumulative oil and gas production until May 2016 is 44.13 MMSTB and 13.27 BSCF.

The field produced gas, with an average gas-oil ratio of 300 scf/stb and with a small amount of water. This water production comes primarily from wells producing on ESP (especially after work-overs) and is unlikely to be entirely formed water. Insignificant water influx from aquifers has been observed.

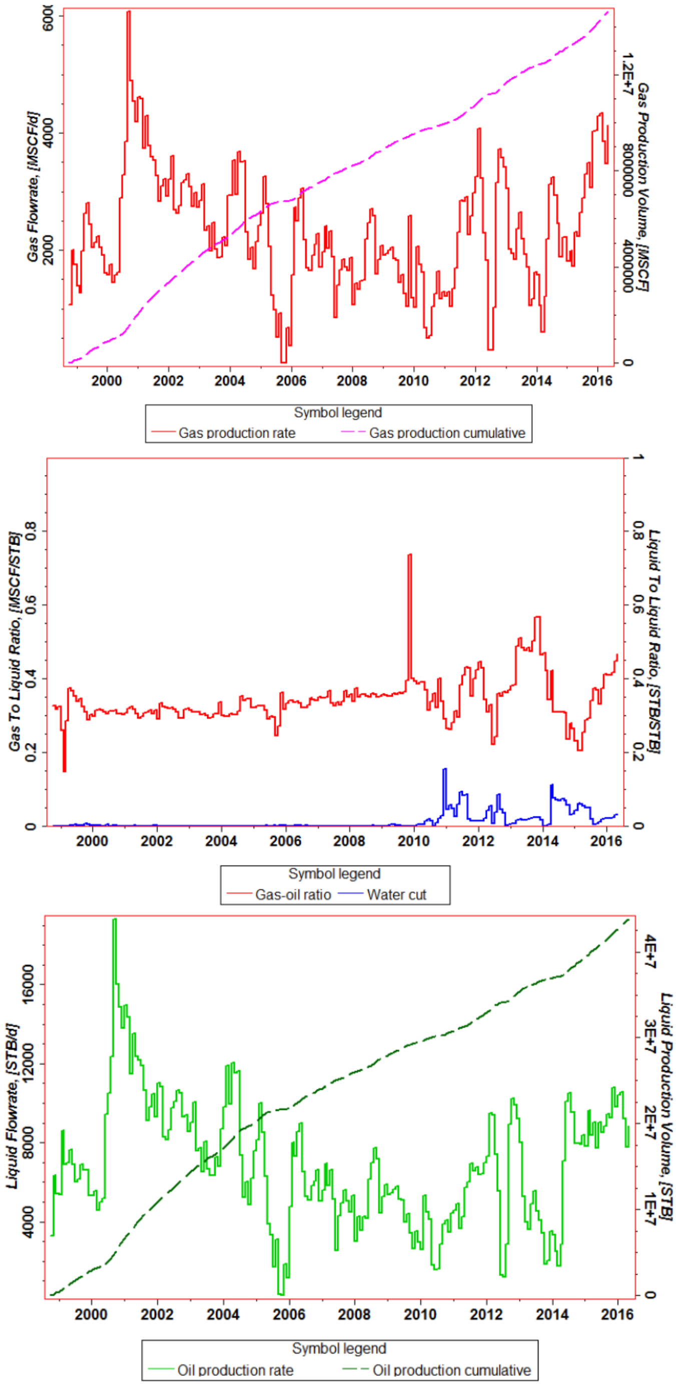

Fig. 3. Production history charts for the studied field

Prioritization of Technological Challenges

Based on the documents, field reports, and production history available in the oil field under study, not all the mentioned challenges have the same probability of existence. In other words, some problems are proven, and some problems are only speculative. Nevertheless, the problems can be categorized into three levels and assigned a score for prioritization:

- Low probability challenge: 1 point
- High or significant probability challenge: 2 points
- Certain challenge: 3 points.

The scoring system provided categorizes challenges based on their probability of existence in the oil field.

For challenges with a low probability of occurrence (1 point), they are considered less likely to impact operations significantly. Therefore, these challenges are assigned a lower score to reflect their lower priority for immediate action.

Challenges with a high or significant probability of occurrence (2 points) are more likely to affect operations and may require closer monitoring or proactive measures to address them before they escalate further.

Certain challenges (3 points) are those that have been verified to exist based on field reports and production history. These challenges are deemed critical and urgent, warranting immediate attention and action to mitigate their impact on operations.

To produce oil from an oil well, two main stages must be carried out: entering oil from the reservoir into the well, and transporting the delivered oil from the bottom of the well to the surface. Another important factor is the level of impact of each challenge on the overall flow of oil from the reservoir to the surface, which is categorized into 5 different cases as presented in Table 3.

Table 3. Ranking of the impact of problems on the overall oil flow from the reservoir to the surface.

Very high	High	Medium	Low	Very low
5 points	4 points	3 points	2 points	1 point

Based on the expert committee's opinions and analysis, ten challenges were prioritized in the previous stage. These ten challenges were presented in the technology roadmap development steering committee meetings. The technology roadmap development steering committee is a combination of different experts from universities, oil companies, and the research and technology management directorate of NIOC. The following three challenges were agreed upon as the priority challenges for the oil fields, and it was decided to develop a technological solution tree for each of them.

1. High uncertainty in data
2. High volume of fluid loss during well drilling and completion
3. Low productivity of the wells.

High uncertainty in the field data: It is necessary to implement a field redevelopment plan including drilling new wells and using more efficient drilling/completion methods, along with the selection of enhanced oil recovery methods. Comprehensive geological and reservoir studies based on production and geophysical-geological data should be conducted to improve the structural geological model of the field optimize production and increase well and reservoir-oriented production. An intelligent and automatic framework for production optimization should be considered.

The challenge of fluid loss in well completion to the reservoir: Fluid loss during drilling/completion leads to well blowouts, stuck pipes, high costs, and delays in drilling operations. Fluid loss is facilitated by improper cleaning of the wellbore, the weight of drilling fluid, reservoir properties, heterogeneity, and the presence of fractures. Controlling fluid loss is essential, and the use of fluid loss control materials in preventing its penetration into the reservoir and damage to the wellbore and reservoir is useful. The entry of drilling fluid into the reservoir and the formation of hard deposits cause problems and stop the pump shaft from circulating inside the well.

Low well productivity index: A low well productivity index is often associated with low reservoir permeability and high formation damage. These factors can significantly impact the final production rate in oil fields. Various challenges can arise during the production stages, leading to reduced efficiency and production delays. Solutions to improve the efficiency of low reservoir wells and address reservoir problems are crucial for enhancing production efficiency. Flow issues in the well and manifold, formation of organic and inorganic scales, and problems with the recovery system are among the production challenges that require suitable solutions.

Identifying Technological Solutions Using the Technology Tree

In this section, based on the reviewing of many papers, and international and domestic reports, as well as conducting interviews with academic and industrial experts in this field, technological methods, and solutions have been identified for the three mentioned challenges. For the challenges of high data uncertainty in the field and fluid loss during well drilling, separate technology trees have been drawn. Through discussions and reviews conducted in the steering and expert committees, three priority technological solutions were selected for the low productivity challenge, which can be seen in the technology tree of Figs. 7-11. As many solutions can be applied to improve well productivity, they could not be included in the low-productivity challenge technology tree. Therefore, a separate tree has been drawn for each of those techniques.

Prioritizing Technological Solutions Using the Morin Model

In the previous section, various methods for identifying technological solutions were introduced and the technology tree drawing method was selected based on the expert team's opinion. Then, for each of the three challenges, a technology solution tree was drawn and the methods and solutions were explained under each tree. In this section, the technological solutions introduced in the previous section will be prioritized. Typically, in identifying key technologies, questions are asked such as: Which areas are key for development? Which vital technologies require public resource support? What criteria should be used to select vital technologies? What indicators are used to measure each criterion? Based on the selected criteria, which technologies are a priority for development and investment [25]? The proposed method for this component is based on summarizing various national and industrial technology strategies. The Morin model focuses on two criteria attractiveness and capability in selecting important technologies. The proposed improved attractiveness-capability model for prioritizing technologies in developing countries uses a two-dimensional attractiveness-capability matrix. In this model, the concept of capability is used to consider existing and potential potentials. Also, two critical criteria of technology intelligence and design principles are used to complete the matrix. For example, technology life cycle analysis is used to evaluate the risk of developing obsolete technologies and the dependence of technology on specific materials or components. Finally, efforts to localize special materials and components under any conditions are recommended [26, 27]. During the expert technical sessions and the steering committee, it was finally decided that the prioritization criteria for technological solutions should be determined based on the three main challenges as well as the attractiveness and capability criteria of technology. Therefore, the following five criteria were introduced for prioritizing technological solutions.

We chose to utilize a qualitative approach in our evaluation of criteria such as competitive advantages and costs in the field of petroleum engineering due to the lack of precise numerical data. This is a common practice in the industry when dealing with complex and multi-criteria evaluations, as obtaining accurate quantitative data can be challenging.

For us, the exact numerical values of each of these criteria were not very important. What mattered to us in evaluating these technologies, comparing them, and assessing their attractiveness and capabilities was to compare the technologies with each other. In this comparison, the relative superiority of the technologies is important, not necessarily the specific numerical values. Some of these may be future technologies with unclear quantitative values. In these multi-criteria decision-making processes, things become very complex as the number of factors increases, the number of decision options rises, and pairwise comparisons based on expert opinions are mainly used. Methods like AHP can be utilized, which essentially combine qualitative and quantitative approaches. Generally, in these multi-criteria decision-making processes involving multiple options and pairwise comparisons, the expertise and opinions of specialists are relied upon.

In the context of evaluating the attractiveness of different technologies in the oil and gas industry, factors such as costs, sales, exports, and competitive advantages are crucial for decision-making. Therefore, if there is any evaluation or analysis regarding these factors, it should be included in the article to provide a comprehensive understanding of the technology assessment process .

It is essential in the oil and gas industry to consider all relevant criteria, including both quantitative and qualitative aspects, to make informed decisions about technology selection and implementation. The integration of both types of evaluations can provide a more holistic view and lead to better decision-making in this complex and dynamic industry.

Criteria for prioritizing technological solutions considering three main challenges, as well as attractiveness and technology feasibility criteria:

1. Impact on the field under high uncertainty.
2. Impact on wellbore fluid loss and completion.
3. Impact on low well productivity.
4. Technology attractiveness impact.
5. Technology feasibility impact.

The criteria of attractiveness represent intrinsic dimensions of options that are desirable for policymakers. On the other hand, capability criteria seek to evaluate the potentials available in selecting each of the options. In this method, each of the technology domains can be considered in terms of attractiveness and capability in a matrix, and the domains with suitable positions can be chosen. The matrix mentioned in the text could be a decision matrix or a scoring matrix used to evaluate and compare different options based on attractiveness and capability criteria [28].

Some of the criteria for evaluating the attractiveness of different technologies are as follows [29]:

1. Cost of accessing technology.
2. Level of demand for technology.
3. Rate of growth and diversity of technology applications.
4. The urgency of accessing technology in the shortest possible time.
5. Contribution to achieving goals.
6. Potential to create/strengthen competitive advantage.
7. Risk of successfully accessing technology.
8. Level of ease of accessing technology.
9. Level of environmental compatibility.

The criteria for evaluating the feasibility of technologies are as follows [30]:

1. Hardware: Technical equipment and laboratory equipment required for technology development
2. Human ware: Human resources with relevant education, sufficient experience, and interdisciplinary expertise for technology development
3. Software: The level of knowledge/experience accumulated from executing projects related to technology in the organization, specialized software required for technology development, and the level of access to information resources required for technology development.
4. Brainware: This can be defined as the combination of human ware and software criteria, which are essential for successful technology development.

The development of well-based technologies in the Iranian oil industry is crucial for sustainable growth. These methods enhance production efficiency, reduce costs, and improve operational performance. Well-based technologies are ideal for achieving effective and economical oil production, especially in current economic conditions.

Feasibility assessment in software, hardware, and human capabilities is essential for evaluating the practicality and viability of implementing technological solutions in the oil industry. This assessment ensures that chosen solutions are innovative, beneficial, financially viable, and feasible to implement, leading to successful outcomes.

Key aspects of feasibility assessment include:

1. Technical Feasibility: Examining practical implementation in the oil field environment, including compatibility, integration ease, and technical risks.
2. Economic Feasibility: Assessing economic viability through investment costs, operational expenses, cost savings, and return on investment.
3. Human Capabilities: Evaluating human resources with relevant education and experience for technology development.
4. Hardware and Software: Assessing technical equipment, specialized software, and information resources required for technology development.

Considering these factors ensures that technological solutions are not only innovative but also practical and feasible for successful implementation in the oil industry.

Questionnaires have been prepared for prioritizing technologies for each challenge separately. For example, a questionnaire has been provided for the challenge of high uncertainty in field development. This questionnaire contains a pairwise comparison table that examines the attractiveness and feasibility of the technology, and the share of technology in solving this challenge to determine the weight of each criterion. The three criteria are the attractiveness of technology, feasibility of technology, and high uncertainty in the field.

The attractiveness criterion consists of criteria that determine the economic and strategic attractiveness of technologies, such as total cost, sales and exports of technology, level of demand for technology (especially in other domestic oil fields), potential to create/strengthen competitive advantage, etc. [27]. The feasibility criterion consists of the level of hardware, software, and human resources related to the design, construction, and operation of technology within the country [27].

Table 4 shows the preference of each criterion relative to the opposing criterion based on the spectrum of Table 5. For example, in the first row, if the attractiveness criterion is 7 times better than the feasibility criterion, the number 7, which is close to the attractiveness criterion and on the right side of the table, should be drawn with a line.

In the second part, Table 6 examines the solutions from the perspective of each criterion. Using the following scoring spectrum, the share of each solution in achieving the desired criterion is determined.

Table 4. Scoring spectrum for questionnaire criteria

Value	Comparison	Explanation
1	Equal preference	Criteria A and B have equal importance
3	Slightly preferred	Criteria A is slightly more important than B
5	Moderately preferred	Criteria A is significantly more important than B
7	Strongly preferred	Criteria A is much more important than B
9	Extremely preferred	Criteria A is completely more important than B
2-4-6-8	Intermediate preferred	These values indicate intermediate values

The scoring spectrum provided in Table 4 is used to assign values to the importance of criteria in a questionnaire. In the context of petroleum engineering, this scoring system can be utilized to evaluate different criteria related to oil and gas exploration, production, or refining processes. For example, when assessing the importance of criteria such as reservoir quality, production efficiency, environmental impact, or economic viability, the scoring spectrum can help prioritize these factors based on their significance in a particular project or decision-making process. By using this system, engineers in the oil and gas industry can make informed choices and optimize their operations based on the relative importance of different criteria.

Table 5. Three-way comparison of criteria related to technology attractiveness, technology feasibility, and share in solving the challenge

Criterion A	Priorities																	Criterion B
Technology feasibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology attractiveness
Share in solving the challenge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology attractiveness
Share in solving the challenge	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technology feasibility

Score very Low	Score Low	Score Average	Score High	Score Very high
1	3	5	7	9

Table 6. Questionnaire for prioritizing technological solutions to overcome high uncertainty in the field data

Target Area	Effective Methods	Technological Solutions	Share in Managing the Field under High Uncertainty	Technology Attractiveness	Technology Feasibility
Closed loop	Closed loop management and development in a field	Closed loop field management and development on a model	-	-	-
		Closed loop field management and development on multiple models	-	-	-
		Updating models at a fixed interval	-	-	-
		Updating models at a variable interval	-	-	-
	Closed loop management and	Closed loop field management and	-	-	-

	development in a reservoir	development on a model			
		Closed loop field management and development on multiple models	-	-	-
		Updating models at a fixed interval	-	-	-
		Updating models at a variable interval	-	-	-
Open loop	Open loop history matching	History matching	-	-	-
	Open loop optimization	Optimization	-	-	-

Prioritization and Validation of Key Technologies

In this article, the validation of results was carried out through questionnaires and interviews with experts and specialists in the working group. Initially, the attractiveness and capability of technologies in each field were completed by members of the specialized team through a questionnaire. Then, after reviewing the history of fields and holding expert sessions with the technical team of oil companies, the challenges of oil fields were identified and prioritization criteria were determined based on them. Based on this information, technological solutions for each challenge were identified and prioritized using sound prioritization criteria. The expert team and the criteria steering committee approved the prioritization criteria, and after prioritizing the solutions related to each challenge, the style and method of acquiring priority technologies were determined. Finally, a roadmap for oil field technologies was developed. This method was used in collaboration with and with the approval of relevant experts and specialists to achieve more accurate results and greater credibility.

Results and Findings

Priority Technology Challenges Have Been Identified in the Oil Field

As stated, by examining the production data of the studied field, the challenges were divided into two categories related to reservoir behavior and well behavior (Fig. 4).

The article focuses on the identification and prioritization of challenges and development technologies in one of Iran's oil fields using a well-based approach. It utilizes the Technology Tree and Morin Model to identify and prioritize challenges and solutions, emphasizing the importance of technology-based solutions in overcoming challenges such as reservoir pressure, water production, and low reservoir productivity. The study involves collaboration with experts and specialists to validate results and prioritize technological solutions. The document also highlights the significance of feasibility in implementing technological solutions and provides a systematic approach to prioritize and focus on the most effective solutions.

In this manuscript, a notable innovation resides in its holistic strategy toward recognizing and prioritizing key obstacles unique to the Iranian oil sector, especially within the realm of well-based technologies. The incorporation of advanced methodologies like the Technology Tree and Morin Model stands out as integral in pinpointing and sequencing challenges and solutions, offering a structured and evidence-based route to tackling the distinctive hurdles prevalent in Iran's oil fields. Moreover, a strong emphasis is placed on fostering collaboration with industry experts and specialists, along with the crucial step of validating outcomes to ensure the feasibility and efficacy of the proposed technological remedies.

This distinctive approach distinguishes the manuscript by presenting a tailored and methodical framework for addressing the precise challenges encountered in the Iranian oil industry, elevating it above prior studies. By integrating modern techniques and emphasizing the significance of expert consultation and result validation, the manuscript not only identifies challenges but also offers strategic solutions in a systematic and industry-relevant manner. This structured methodology holds the potential to significantly enhance problem-solving approaches within the dynamic landscape of the Iranian oil sector, paving the way for informed and effective decision-making processes.

Through a comprehensive engineering lens, this manuscript signifies a significant step towards navigating and mitigating the complexities inherent to the Iranian oil industry, underscoring the importance of strategic planning, collaboration, and evidence-based solutions in overcoming industry-specific challenges. It serves as a beacon of innovation and practicality in the domain of petroleum engineering research, showcasing the potential for tailored methodologies to drive impactful advancements and solutions within the intricate framework of the Iranian oil sector.

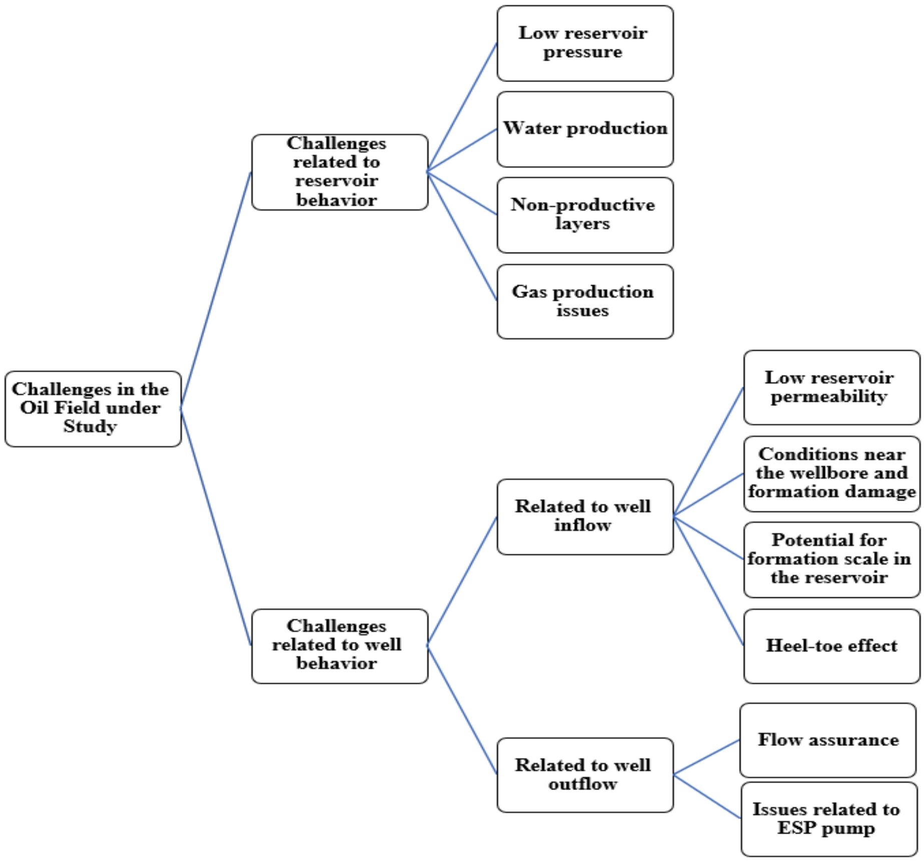

Fig. 4. Priority technological challenges in the studied oil field. Translate the text into English

1. The average reservoir pressure, natural pressure, and initial pressure of an oil reservoir at the start of production are important factors. A decrease in reservoir pressure over time can lead to problems such as reduced productivity and oil production. Variations in average reservoir pressure can cause uncertainty in well and reservoir behavior, affecting wellbore and surface pressures, and surface network modeling, increasing uncertainty. According to the study conducted for the field under consideration, the reservoir pressure was around 1980 psi.
2. Water production is a significant challenge in many Iranian oil fields, as the amount of water produced increases simultaneously with oil production. Proper and efficient

management and disposal of produced water is vital and challenging for the oil industry. Some wells in the studied field have up to 40% water cut.

3. Non-productive layers exist in some Iranian oil fields, hindering oil flow and causing drilling and production issues. Some wells in the studied field have non-productive layers of a certain thickness. Gas production problems in some Iranian oil fields can lead to excessive gas production, resulting in reservoir pressure reduction and decreased oil production. Some wells in the studied field have faced this issue.
4. Heel-toe Effect in oil fields is a type of frictional pressure drop that leads to a decrease in reservoir pressure and oil production. It limits the water influx during oil production due to the non-productive layer and water intrusion into higher fields. Horizontal wells have a higher risk of unintentional gas and water coning due to high frictional pressure drop compared to vertical wells. Some wells in the studied field have faced this problem.
5. Low reservoir permeability in some Iranian oil fields can cause a decrease in the well inflow rate. This problem reduces the reservoir's absorption power and porosity, resulting in reduced oil production. The average permeability in the studied field was less than 1 millidarcy. Some Iranian oil fields face conditions close to the wellbore and may cause formation damage. Formation damage occurs due to the intrusion of any foreign fluid that reduces permeability, clogs holes, and reduces porosity. The factors causing formation damage include solid invasion, sediment deposition, and migration of fine particles.
6. Flow assurance in the oil industry means maintaining and controlling the output flow from the well. It includes ensuring the stability and continuity of oil flow and controlling the output based on environmental and production constraints. In evaluating flow assurance, the impact of hydrocarbon fluid solids such as asphaltene, wax, and hydrate on disrupting the flow system is examined. Problems such as multiphase flow composition including gas, oil, water, and solid materials such as sand and gravel, as well as issues such as deposits, asphaltene deposits, wax deposits, and hydrate formation, were observed in the studied field.

Regarding the problem of excess water production in the studied wells:

In terms of the most appropriate and economical method for addressing excess water production in oil wells, the article suggests the use of fluid loss control materials, intelligent production systems, and hydraulic fracturing as potential solutions. These methods aim to optimize production flow, control well parameters, and enhance reservoir performance, which could help mitigate excess water production. However, the most appropriate and economical method would depend on the specific characteristics of each well and the underlying geological and reservoir conditions. The most appropriate and economical method for managing excess water production in oil wells would depend on the specific circumstances of each well. Some common methods include installing downhole equipment like gas lift systems or plunger lift systems to help lift the water out of the wellbore, implementing water shut-off techniques such as chemical treatments or mechanical barriers, or even considering enhanced oil recovery techniques like water flooding to manage water production. A comprehensive assessment of the well-specific challenges and the feasibility of implementing different solutions would be necessary to determine the most suitable and cost-effective approach for addressing excess water production in the studied wells.

An Example of Rating the Impact of One of the Challenges on the Overall Flow of Oil from the Reservoir to the Surface

The text describes how challenges were evaluated based on expert opinions and field data, with a specific focus on gas production. The results of this evaluation are presented in Table 7.

Table 7. Ranking of the impact of problems on the overall oil flow from the reservoir to the surface

Very high	High	Medium	Low	Very low
5 points	4 points	3 points	2 points	1 point

Overall summary of prioritizing challenges qualitatively and quantitatively

The overall conclusion of prioritizing challenges in a scoring format is presented in Table 8 and in a percentage format in Fig. 5.

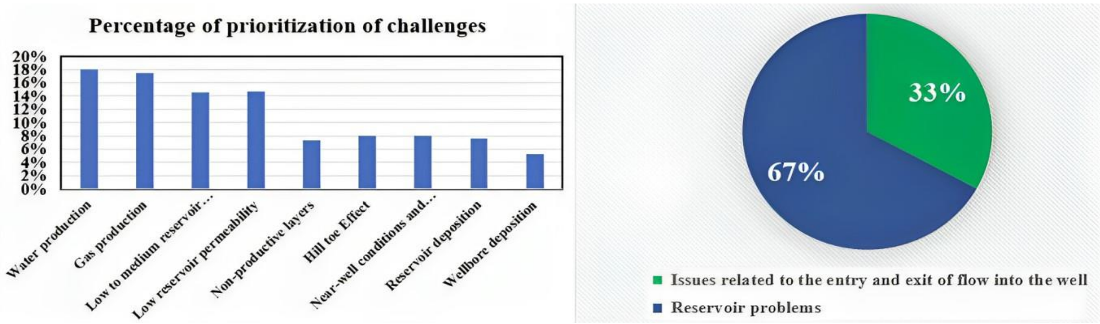

Fig. 5. Overall conclusion of prioritizing challenges in percentage

Table 8. Overall summary of challenge prioritization.

Name of Challenge	Probability	Impact on Well Input	Impact on Well Output	Impact on Total Flow	Total Score
Water production	3	1	1	5	10
Gas production	3	1	0	5	9
Low to medium reservoir pressure	3	1	0	4	7
Low reservoir permeability	3	1	0	5	9
Non-productive layers	2	1	0	2	5
Hill toe Effect	2	1	0	2	5
Near-well conditions and formation damage	1	1	0	2	4
Reservoir deposition	1	1	0	2	4
Wellbore deposition	1	1	0	1	3

Finalizing Prioritized Challenges of the Studied Oil Field

After discussing and examining the challenges and the results of the studies, the following three challenges were agreed upon as the priority challenges for the oil fields, and it was decided to develop a technological solution tree for each of them (Fig. 6).

Fig. 6. Finalizing prioritized challenges of the studied oil field

Each of these challenges will be explained below.

Introducing the challenge of high data uncertainty in the field to increase oil production: It is necessary to implement a field redevelopment plan including drilling new wells and using more efficient drilling/completion methods, along with pilots of enhanced oil recovery methods. Comprehensive geological and reservoir studies based on production and geophysical-geological data should be conducted to improve the structural geological model of the field, optimize production, and increase well and reservoir-oriented production. An intelligent and automatic framework for production optimization should be considered.

Introducing the challenge of fluid loss in well completion to the reservoir: Fluid loss during drilling/completion leads to well blowouts, stuck pipes, high costs, and delays in drilling operations. Fluid loss is facilitated by improper cleaning of the wellbore, the weight of drilling fluid, reservoir properties, heterogeneity, and the presence of fractures. Controlling fluid loss is essential, and the use of fluid loss control materials in preventing its penetration into the reservoir and damage to the wellbore and reservoir is useful. The entry of drilling fluid into the reservoir and the formation of hard deposits cause problems and stop the pump shaft from circulating inside the well.

Introducing the challenge of low reservoir productivity: The productivity index of production is the determining factor in the final production rate in the oil field. Various problems can arise during the production stages and in surface facilities of oil fields, leading to reduced efficiency and production delays. There are solutions to improve the efficiency of low reservoir wells and solve reservoir problems that improve production efficiency. Also, flow issues in the well and manifold, formation of deposits and crystals, and problems with the recovery system are among the production challenges that require a suitable solution.

Technological Solutions for Challenges

In this section, based on the analysis of articles, international and domestic reports, and interviews with academic and industrial experts in this field, methods, and technological solutions have been identified for the challenges in the studied field.

Tree of Technological Solutions to Address the Challenge of High Uncertainty in Field Data

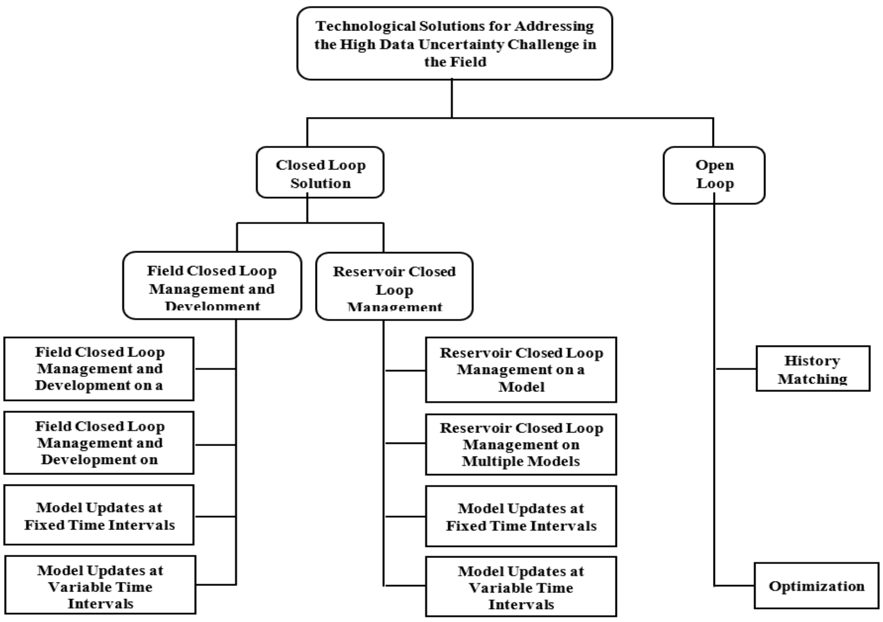

Fig. 7. Tree of technological solutions to address the challenge of high uncertainty in field data

Tree of Technological Solutions to Address the Challenge of Fluid Loss in Well Completion

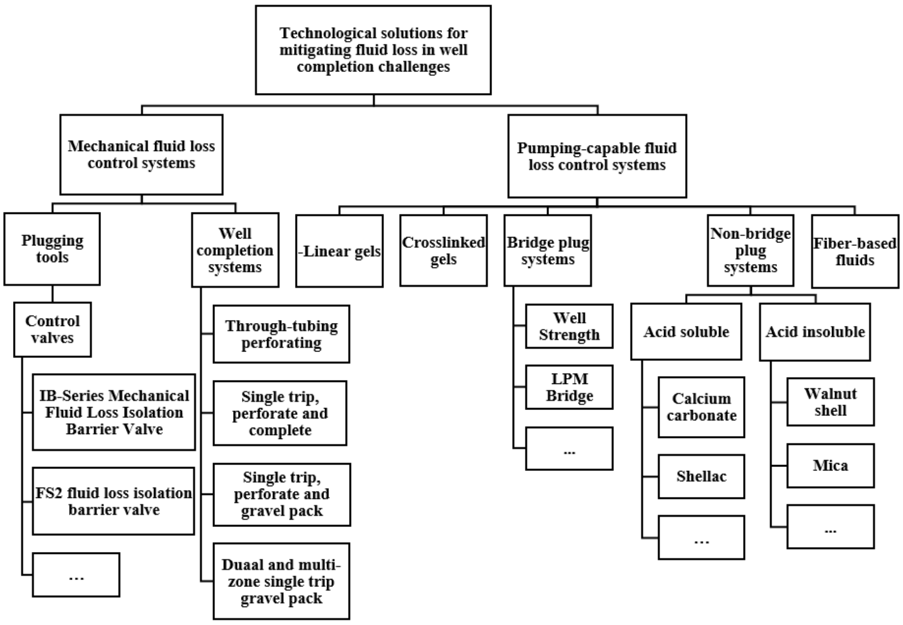

Fig. 8. Tree of technological solutions to address the challenge of fluid loss in well completion

Tree of Technological Solutions to Address the Challenge of Low Reservoir Productivity

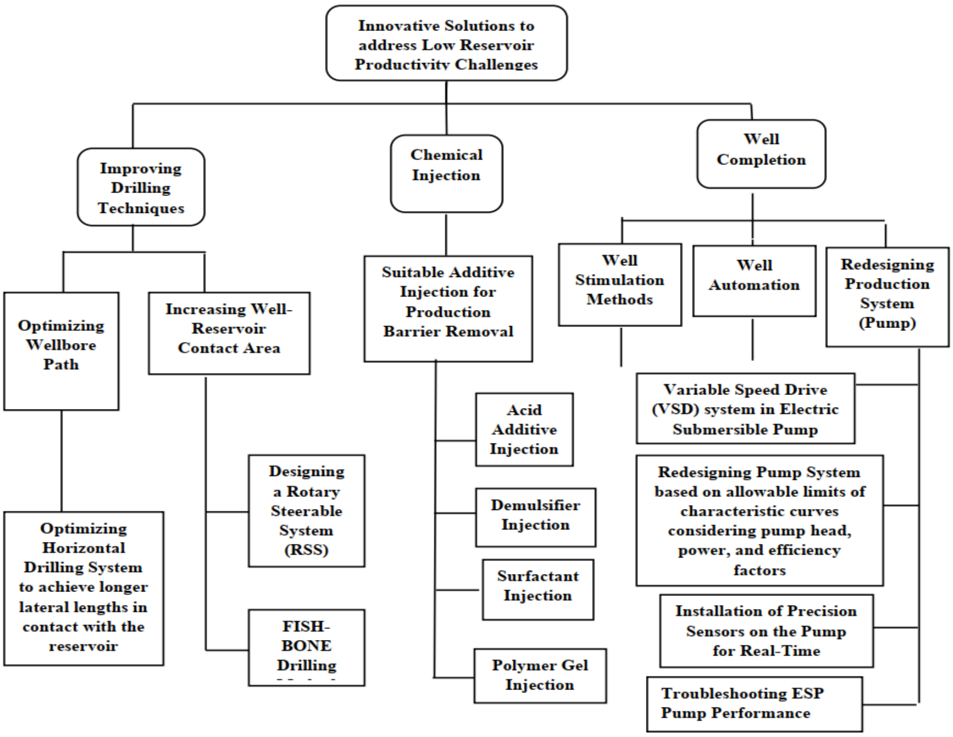

Fig. 9. Tree of technological solutions to address the challenge of low reservoir productivity

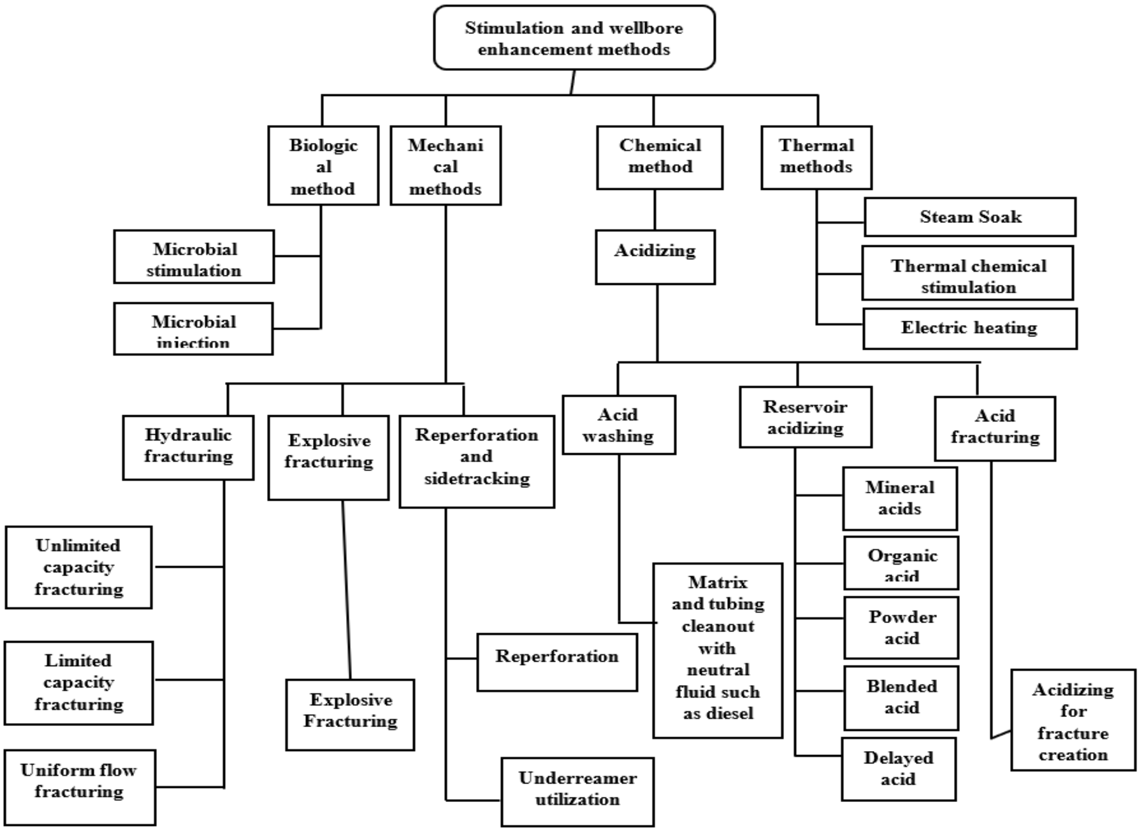

Fig. 10. Tree of technological solutions to address the challenge of low reservoir productivity (stimulation and well stimulation methods)

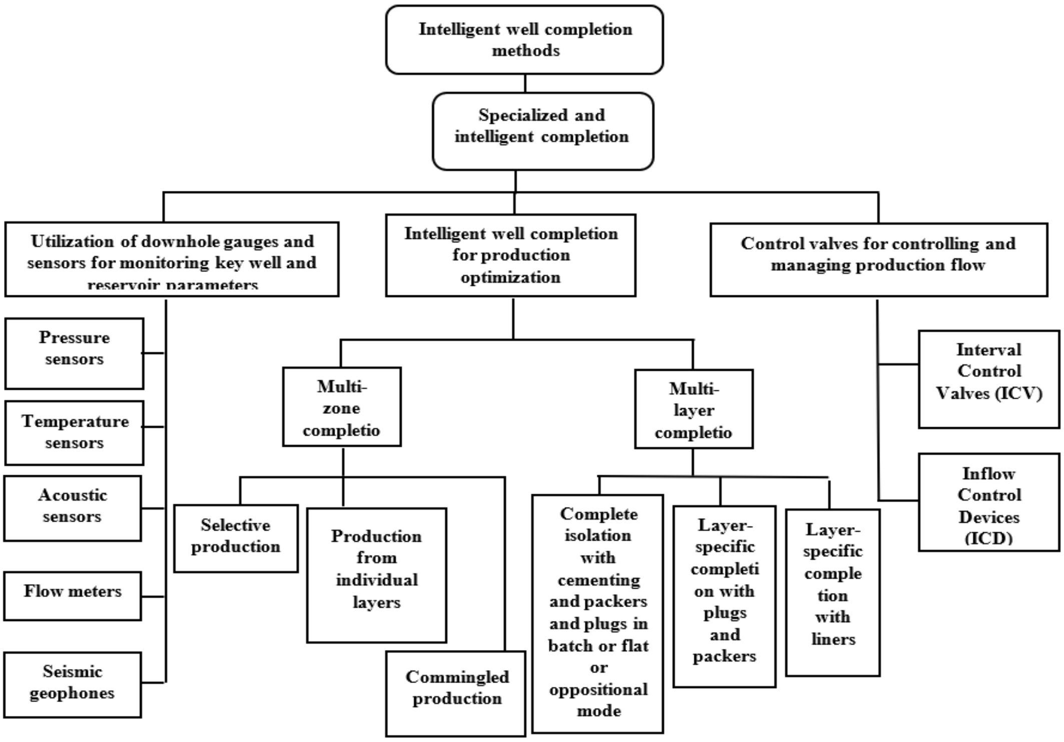

Fig. 11. Tree of technological solutions to address the challenge of low well productivity (smart well technology methods)

Discussion

Open and closed-loop reservoir management methods are used to control and improve the productivity of oil fields. The major challenge in these methods is the instability and uncertainty of data obtained from the oil field. Instability in data refers to the variability and lack of consistency in the data obtained from the oil field. This can be due to various factors such as measurement errors, incomplete data sets, or changing reservoir conditions. Instability in data can make it challenging to make accurate predictions and decisions regarding reservoir management strategies. Improving decision-making in reservoir management uses artificial intelligence and deep learning capabilities to reduce data uncertainty in the oil field. Artificial intelligence methods using neural networks and unsupervised learning can help reduce data uncertainty and specifically, neural networks can assist in the history-matching process and production optimization. Thus, technological solutions for managing open and closed-loop reservoirs can be effective in reducing data uncertainty in oil fields.

Mechanical control systems, blocking tools, and control valves can be used as technological solutions to control fluid loss in well completion. These systems and tools prevent fluid loss by creating barriers in the flow path of well completion fluids. Well completion systems also provide the ability to complete wells with reduced fluid loss using various methods such as perforated mesh screens, gravel packs, etc. Pumping systems with the ability to pump fluids can also reduce fluid loss using linear and cross-linked gels and bridging systems such as IPM bridges. Non-bridging systems can also reduce fluid loss using materials such as acid solvents, calcium carbonate, and shell casing. Fiber-based fluids with their unique properties such as long fibers and low seepage can be used as a technological solution to reduce fluid loss in well completion.

Based on the Tree of technological solutions, the following technological measures can be taken to address the challenge of low reservoir productivity in oil fields:

1. Using a completed and intelligent production system including control valves for controlling and managing production flow, inlet flow control valves, and production distance control valves.
2. Using precise sensors on pumps for real-time monitoring of their performance and troubleshooting of electric submersible pumps.
3. Improving drilling methods such as RSS directional drilling and FISH-BONE drilling and optimizing the wellbore path to improve contact between the well and the reservoir.
4. Using downhole sensors to monitor key parameters of the well and reservoir including pressure sensors, temperature sensors, acoustic sensors, flow meters, and geophones.
5. Using hydraulic fracturing to increase production flow with unlimited/limited capacity and uniform flow.
6. Using acidizing and injecting suitable additives to remove production barriers, increase flow, and improve the quality of produced oil.
7. Employing smart systems in producing wells, including variable speed change systems in pumps and optimizing the production system to increase efficiency.
8. The combination of these technological solutions can significantly improve the efficiency of oil fields and optimize reservoir operation.

Conclusion

In conclusion, this article provides a comprehensive overview of the prioritization of technological challenges within an Iranian oil field, particularly focusing on reservoir and well behavior. Through a systematic approach involving expert meetings and technical analysis, three main challenges were identified and prioritized, leading to the development of a technology tree for each challenge. The validation of results through expert interviews and questionnaires further solidified the findings.

First, the article underscores the importance of prioritizing feasibility in addressing complex oil challenges. Feasibility encompasses technical, economic, and operational aspects crucial for successful implementation within the oil industry context. This emphasis ensures that chosen technological solutions are not only innovative but also practical, financially viable, and compatible with existing infrastructure.

Second, the article highlights the significance of collaboration and validation in the decision-making process. The involvement of expert committees and specialists in prioritizing challenges and developing technological solutions enhances the credibility and applicability of the findings. Validation through questionnaires and interviews further strengthens the reliability of the proposed roadmap for oil field technologies.

Third, the article delineates key technological solutions for addressing the identified challenges. These include improvements in drilling methods, utilization of downhole sensors, hydraulic fracturing, acidizing, and implementation of smart systems in producing wells. Such solutions aim to enhance efficiency, boost production, and revive low-yield or inactive wells, aligning with national policies and objectives.

Fourth, the article emphasizes the role of data management and uncertainty reduction in addressing oil field challenges. By managing data uncertainties effectively and employing appropriate methods such as well-based approaches, the article suggests significant improvements in well performance and efficiency can be achieved.

Finally, the article underscores the importance of setting correct priorities and aligning technological solutions with national policies. By focusing on the identified challenges and implementing suitable methods, the article suggests that increased production and more effective management can be attained within shorter timeframes and at lower costs.

In summary, through a comprehensive analysis of technological challenges, prioritization criteria, and feasible solutions, this article provides valuable insights for the oil and gas sector, emphasizing the importance of collaboration, validation, and strategic decision-making in addressing complex industry challenges.

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