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Designing Enhanced Oil Recovery (EOR)/Improved Oil Recovery (IOR) Technology Road Map in Oil Fields

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Highlights

- The issue of creating, developing, and equipping specialized centers for EOR; raising skills, expertise, and knowledge; and transferring technology as sustainability achievements are critical.
- The outputs and results of each stage and technological solutions to challenges are highly emphasized and essential.

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Abstract

The oil industry is looking for a way to develop reservoir management and optimal production of hydrocarbon reservoirs. The use of advanced technologies in the extraction of oil and gas reserves is essential in advancing the short-term and long-term goals of this industry, both in terms of product type and process. A technology road map is a plan that implements short-term and long-term goals using technology solutions to help achieve the goals. The technology road map for enhanced oil recovery (EOR)/improved oil recovery (IOR) of oil fields has been developed based on the emphasized fields and areas of the target technology. It has been expressed in 10 years according to the existing challenges and preventive measures, and all research and executive activities will be carried out with a focus on the road map. In this research, using the case study research method, by studying nine cases of research conducted in the research and technology of the National Iranian Oil Company, a map of executive achievements and technological solutions in each of the target technology areas, namely reservoir, well, and the facilities, are identified and presented based on the challenges and implementation stages. The results of this study show that in this road map, the issue of creating, developing, and equipping specialized centers for EOR; raising skills, expertise, and knowledge; and transferring technology as sustainability achievements are critical. In addition to other achievements, outputs and results of each stage and technological solutions to challenges are highly emphasized and essential.

Keywords: EOR, Goal, Hydrocarbon, IOR, Plan, Reservoir, Road map, Strategy, Technology

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1. Introduction

One of the standard methods of long-term planning is to prepare a road map for the area. In a simple definition, it can be stated that the road map is the method of discovering and describing the desired future and explaining how to achieve it in a simple and understandable language for the organization. One of the most widely used road maps is the technology road map, which is widely used in various industries for strategic and long-term planning. In the oil industry, technology development priorities have always been considered, and studies in this field have been conducted by reputable oil companies, one of which is the studies conducted by Shell Company in Kazakhstan oil and gas production. Iran's oil industry has always sought a way to develop reservoir management and optimal production of hydrocarbon reservoirs to use advanced technologies to extract oil and gas reserves, reduce production costs, and increase recyclable reserves. Therefore, the role of technologies, both in terms of product type and process, will be significant in advancing the short-term and long-term goals of this industry. This research focuses on the technology road map for 10 years that aligns short-term and long-term goals using technology solutions to help achieve the goals. In this research, using the case study method, studying nine cases of research conducted in the research and technology of the National Iranian Oil Company, and using studies conducted by oil companies and other researchers and their localization have been done .

The difference between this research and other works is in the focus and comprehensiveness of this research on achieving goals such as achieving technology development strategy in production, maximizing the recovery factor in the reservoir, ease of production operations, reducing operating costs, creating innovation, and using modern technologies with global experience.

Some recent research works have also been introduced in Table 1.

Table 1

Research in the field of the technology road map.

Row	Title	Writers
1	Presenting a Road Map Model for Technologies of an Advanced System	Mir Hossein Akhrooy, 2019
2	The Necessity of Preparing a Technology Road Map for Iran's Health System: A Narrative Review Study	Arab Zusani et al., 2017
3	Information Technology Road Map Mapping: An Approach to Align its Strategies with Business Strategies	Mohebbi and Heidari, 2016
4	Assessment of Technology Development Risks in Different Layers of Technology Road Map (Case Study: Drilling Drills)	Naghizadeh et al., 2016
5	Oil and Gas Upstream Technology Road Map in Leading Countries (Case Study: Norway–Japan)	Karimi, 2013
6	Strategic Document and Road Map for The Development of Power Industry Robots Technology	Alaee, 2016
7	Approach Modeling and Evaluation Road Map of Defense Systems	Luo and Yu, 2018
8	Development of a Road Map of Airline Technologies for Eight Years	Suraw et al., 2018
9	Industrial Technology Road Map to Support General R & D Planning	Cho et al., 2016
10	Kazakhstan Upstream Oil and Gas Technology and R & D Road map	May 2013

For road map implementation, different stages of implementing EOR operation based on different levels of technology readiness levels (TRL) and classification of technologies, and the classification of output in the form of (deliverables, achievements, and sustainable achievements), responsible for action, and the use of multiple specialized committees along with experts at the national level are considered.

The road map framework is presented in Figure 1 in a multi-step format.

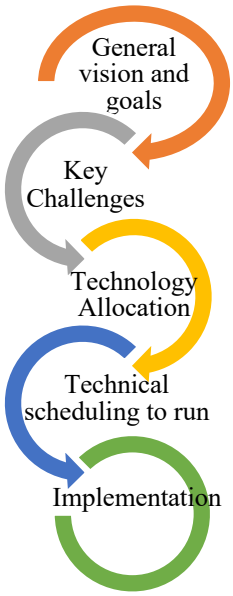

Figure 1

The general road map development process.

As shown in Figure 1, road map development for a field includes identifying the vision and general objectives, identifying and investigating the key challenges, allocating appropriate technology, planning for implementing considered technologies, and implementing the programs.

The vision presents an image of the desired future, which, whenever placed in the minds of the people of the society, paves the way for the changes and transformations of the society. Within the framework of the desired perspective, individual and social planning and movements are directed toward the ideal future. The next step is to identify the priority challenges in the goal field. The recognition of the status quo is done by directly negotiating with the team of technical experts and prioritizing the challenges and appropriate options chosen after selecting the challenge for development in different dimensions. Technology allocation should be done to compare the current situation with the desired situation, and plans should be defined to achieve the goal. In this stage, using models and simulations and examining different results, different scenarios and technologies considered to be implemented are investigated. In the next step, cost-profit analysis should be performed for each of these scenarios/technologies and a better economically selected program. Risk analysis, program development, and, finally, decision-making are the results of this section.

2. Target technology areas in this research

In order to develop the areas of target technology in this project, after reviewing the status of the reservoir and the available data, the challenges in the sections “Reservoir“ and “improved oil recovery (IOR) studies including two parts of wells and surface facilities“ have been examined separately. For this purpose, first, the challenges investigated in these sections have been extracted, and then, the emphasized fields have been determined based on the challenges. According to the current situation, the existing objectives, and prospects, the areas are prioritized.

2.1. Perspective on this research

The vision in the field of technology development in order to optimize production processes and enhance oil recovery in selected fields in The National Iranian Oil Company is as follows:

- Achieving advanced and native technology in field development;
- Realizing technology development strategy in production;
- Maximizing the enhanced oil recovery from reservoirs;
- Easing production operations and reducing operating costs;
- Creating added value by creating innovation and applying up-to-date and experienced global technologies;
- Improving the level of technology and technical knowledge;
- Promoting the cooperation of universities and industry and using the maximum scientific power of the country;
- Improving the technical and laboratory capabilities of the university and creating a fixed structure of enhanced oil recovery in the university.

3. Missions in this research

The missions of this work include:

- Conducting fundamental and theoretical, applied, and developmental research to solve the problems in the fields;
- Improving the quality and quantity of upstream operations in the field;
- Using interdisciplinary research and developing the world's most up-to-date technologies;
- Connecting with domestic consulting companies and international research centers in order to develop targeted fields to transfer new technologies in the upstream field of oil;
- Using efficient and creative Iranian forces and localizing the required expertise;
- Production of reservoirs and proper operation of oil and gas resources;
- Training and empowering industry and university experts.

4. Challenges

Developing a road map for a field includes identifying the vision and overall goals based on upstream documents, identifying and reviewing the existing key challenges, allocating appropriate technology, planning for implementing the intended technologies, and finally, implementing the plans.

A good road map accurately shows the current situation, the desired situation, and how to achieve it, and providing challenges and opportunities in an area provides the best ways to overcome challenges and seize opportunities.

Based on the surveys, the challenges identified in the repository are as follows:

4.1. EOR challenge

- Considerable oil saturation in the gas-invaded zone;
- The high remaining oil in the gas and water-swept zones in the matrix;
- Meager primary recovery;
- High-viscosity oil API gradient;
- Weak aquifer;
- High-pressure drop in the reservoir;
- Low recovery factor.

4.2. IOR challenge/well production enhancement facilities

- Drilling mud loss well cementing problems;
- Thinning oil zone and increasing gas production in wells;
- A big challenge in asphaltene production and well shut due to asphaltene obstacles;
- Improper well-to-reservoir connection;
- Water and gas breakthrough;
- Casing collapse;
- Sand production challenge;
- Water production challenge;
- Reservoir pressure drop/extra water production;
- Ambiguity in well optimum location and well type.
- The process of mapping the development of critical technologies to EOR/IOR in the oil reservoirs of the country.

In order to develop a technology road map, the formation of specialized committees (panels) and obtaining information from stakeholders are required (Ghazi Nouri et al. 2017; Dastranj et al. 2018). Of course, in this research, nine committees have been involved in the research, and experts in the field of the road map have been consulted on the subject under study.

In order to obtain the correct information in different areas of technology and to determine the steps of road map development using the literature on the subject, the participation of these individuals and receiving the opinions of external experts (at the national level) are used. The design and the initial version of the road map are carried out, which needs to be revised and updated over time; new information and theories are received. How to cooperate with committee members and experts is specified in Figure 2.

A technological road map is a time-based chart in which different layers are located side by side, and their ratios are determined by each other. These layers generally include commercial and technical aspects.

5. Methodology

The approach of this research is descriptive quality through a multi-case study. Semi-structured interview tools and documentary studies have been used in field studies. According to the subject area, the statistical population of the research is the organizational unit of research and technology of the oil company, and the participants are selected from experts with sufficient scientific and executive experience in the field of the multiplicity of experts who have the willingness and commitment to cooperate, including managers and officials of technology development, managers, executors and researchers of technology development projects, and those involved in nine specialized committees.

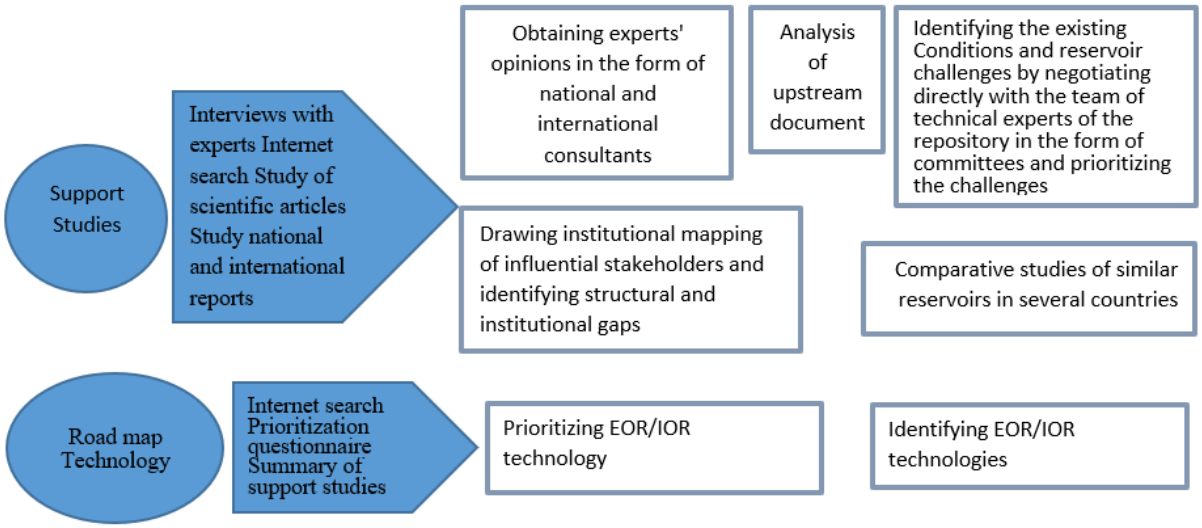

Figure 2

The process of formulating the map development of critical technologies for EOR/IOR in oil reservoirs of Iran.

In analyzing qualitative data, statistical methods are mainly descriptive, and content analysis and coding methods have been used to investigate interview questions.

After completing the intra-case analysis, inter-case analysis is performed to compare and extract similarities and partnerships at all stages and identify the overall road map for each case. Multiple repetitions of the round-trip between the data and theory lead to the construction of an over-harvesting road map.

After compiling a road map for validation and identifying its defects, a meeting is held with all experts preparing the road map to assess the achievements and improve the content and validity of the measures. The results are analyzed, and based on the opinions of the people present at the meeting, the required reforms are carried out in the road map.

Table 2

Categorizing and extracting codes from the interviews.

Extracted open codes		**The first stage of axial coding**	**the second stage of axial coding**
Challenge	**Technology**		
"Considerable Oil Saturation in Gas Invaded Zone", "High Remaining Oil in Gas and Water Swept Zones in Matrix", "Very Low Primary Recovery", "High-Viscosity Oil API gradient", "Weak Aquifer", "High-Pressure Drop-in Reservoir", and "Enhance Oil Recovery"	Water Injection, Gas Injection, Polymer Injection, Foam Injection,	EOR challenge/technology	Challenge/technology
"Drilling Mud Loss Well Cementing Problems"	Using Nano Particles in Drilling Mud/Cement	IOR challenge/technology	

Extracted open codes		The first stage of axial coding	the second stage of axial coding
Challenge	**Technology**		
“Thinning Oil Zone and Increasing Gas Production in Wells”	Using Extra Light Mud/Cement		
	Under Balance Drilling Technology		
	Intelligent Well Technology		
	Drilling Long Horizontal Well		
“Well Shut Due to Asphaltene Obstacles”	Intelligent Well Stimulation Technology		
“Improper Well to Reservoir Connection”			
“Water and Gas Breakthrough”	Water Shutoff/Gas Tracer		
“Casing Collapse”	Using High Schedule Casing		
“Sand Production Challenge”	Using Sand Control Equipment in Surface Facilities		
“Water Production Challenge”	Water Shutoff Intelligent Water		
“Reservoir Pressure Drop/Extra Water Production”	Artificial Lift		
“Ambiguity in Well Optimum Location and Well Type”	Improve Reservoir Model		
“Big Challenge in Asphaltene Production and Well, Shut due to Asphaltene Obstacles”	New Inhibitors to Inhibit Asphaltene Sedimentation		
	Intelligent Well Stimulation Technology		

6. Main components of the road map

A technology road map is a time-based chart in which different layers are placed next to each other, and their relationship to each other is determined. These layers generally include the main technical aspects of interest based on the challenges identified in three activities “reservoir-based”, “well-based”, and “facilities-based”. The challenges will be the focus of the project, and technology deficiencies in priority areas will be identified.

In the road map presented in Figure 3, the following areas of technology are emphasized, along with the technologies needed to achieve the desired situation for each of them. As can be seen, the areas of target technology in this plan include three different areas.

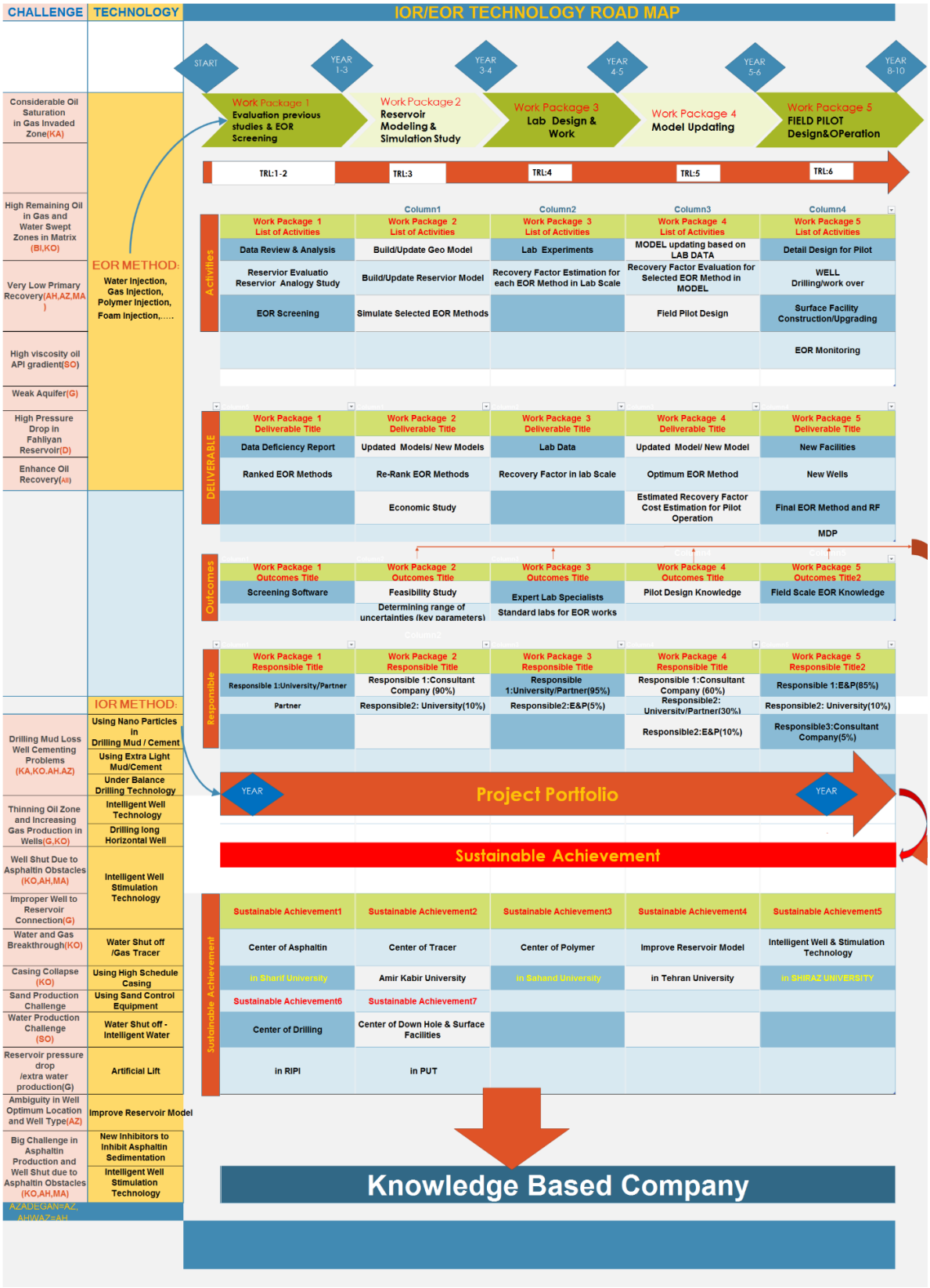

Figure 3

The EOR/IOR technology road map.

The first area of target technology in EOR studies is the reservoir field. In this field, a series of research and technological activities provide the possibility of moving oil in place in conventional methods in

the reservoir, in addition to identifying and resolving the existing problems of the reservoir. Furthermore, the localized executive methods for the reservoir will be considered. These studies will start from the initial screening process, and after the screening, the simulation, laboratory studies, and pilot design in the reservoirs will be done.

Because reservoir activities are focused on increasing the displacement and volumetric efficiencies, some of the influential factors on these efficiencies are identified in the desired reservoirs, and for this purpose, the following activities are recommended:

1. **Evaluation of previous studies and EOR screening**
    - 1.1. Data review and analysis
    - 1.2. Reservoir evaluation and reservoir analogy study
    - 1.3. EOR screening
2. **Reservoir modeling and simulation study**
    - 2.1. Build/update geo model
    - 2.2. Build/update reservoir model
    - 2.3. Simulate selected EOR methods
3. **Lab design and work**
    - 3.1. Lab experiments
    - 3.2. Recovery factor estimation for each EOR method on the lab scale
4. **Model updating**
    - 4.1. Model updating based on lab data
    - 4.2. Recovery factor evaluation for the selected EOR method in the model
    - 4.3. Field pilot design
5. **Field pilot design and operation**
    - 5.1. Detail design for pilot
    - 5.2. Well drilling/workover
    - 5.3. Surface facility construction/upgrading
    - 5.4. EOR monitoring

According to the above explanations and in the screening stage from the first stage of the target field, the challenges of the fields are identified from reservoir challenges and challenges related to wells and surface facilities. Technologies are presented to identify and solve the problems related to the field, and in addition to the results, outputs, and achievements of the responsibility for its implementation are identified, and in the other four stages of the results, The outputs and achievements considered and responsible for the performances are fully identified. A sustainable achievement is mentioned in each stage, the most important of which is creating, developing, and equipping specialized centers for EOR and enhancing skills, expertise, knowledge, and technology transfer. Each of the 5 stages related to the

field of technology targets to EOR within 10 years and in the specified periods in the road map is implemented

The second area of target technology in this project is the field of improved oil recovery, which includes reservoir management, facilities, and wells. In the screening phase, the first target area is jointly investigated, and the challenges of this field are categorized; for each challenge, appropriate technology is considered, and according to the priority of the challenges, the time of implementation of the SARI technological solutions has been determined and specified in the road map. In one of the target technology areas, it is necessary to investigate the proposed specialized programs for field implementation based on the regulations for the technology readiness levels in the reservoir.

The excellent area refers to research and technological activities that, as a result, allow for oil production in place and transfer to the surface. Further, the use of this complex of activities leads to the production of high-quality oil by reducing the production of unwanted fluids (water and gas) and sand, and by changing the properties around the well, it is possible to increase the production rate, reduce damage, optimize hydrocarbon fluid production, and prevent unwanted fluid production.

The field of facilities is research and technological activities carried out to meet the challenges in the field of facilities or to improve and optimize them. These activities can improve, separate, and transfer fluids in surface equipment, reduce retention time and reservoir volume, and prevent heavy hydrocarbon deposition (asphaltene).

One of the leading frameworks considered in this structure is the subject of the technology maturation plan (TMP). The level of technology maturity is planning for developing critical technology elements (CTE) from preliminary levels to high levels of maturity technology. The dynamic relationships between technology readiness levels and the three process areas of fundamental studies are pilots and field studies. Different levels of technology readiness are schematically shown in the road map given. Accordingly, different stages of the implementation of the EOR (from basic studies to complete implementation of operations in a field based on different levels of TRL levels 1 to 9 are given in Table 3. According to the NASA standard, the technology readiness levels are nine stages, and the various stages of EOR operations modeled on the NASA standard are as follows:

Table 3

Different stages of implementing EOR operation based on different levels of TRL.

TRL	Technology development stage	Related activity
1	Basic technology research	Literature study, data review, and analysis
2	Research to prove the feasibility	Reservoir analogy study, reservoir specifications, and EOR screening
3		Lab-scale experiments, reservoir modeling, and simulation study
4	Technology development	Reservoir scale experiments
5		Pilot design
6	Technology demonstration	Pilot execution and validation of the system
7	System commissioning	EOR field execution
8		Completing field execution and performing all required tests
9	System operations	Full-field operation and stabilization of EOR operation

7. Schedule

In order to achieve the mentioned objectives, a program will be set into five parts. The proposed timeframe will mean not only the completion of the work but also the openings that the first results of the studies are tangible: implementation of a road map in the period of 1–2 years for IOR well-based, 2–3 years for IOR facilities-based, and 3–5 years for EOR (as the first step to achieve) the 10-year for field pilot operation.

8. Conclusions and suggestions

This research studied the road map for technologies that have been practical examples in the research and technology management of The National Iranian Oil Company with nine case studies.

The road map for field technology was developed based on emphasized fields and target technology areas according to the existing challenges and preventive measures. This map presented executive actions in each area of target technology based on identified challenges and solutions.

The study was carried out as follows:

In developing the road map of oil fields, the past and current conditions of the reservoir were investigated, and plans were presented for the future of these fields. The critical issue in the road map structure was technologies used in these fields and would be used according to the existing technologies. These technologies were studied in three areas of reservoirs, wells, and facilities with an approach to training and technology transfer, and based on the existing challenges, technological solutions were presented in each field.

The path of EOR technology was developed based on the existing challenges in technology targeting activities and actions, results, outcomes, deliverables, responsibilities, achievements, and sustainable achievements. This map presented executive actions in each area of target technology based on the challenges and solutions identified in the previous section.

One of the topics emphasized in the implementation of the projects in this repository was the issue of technology education and transfer and the establishment of specialized centers for EOR.

In technology transfer, first of all, existing technologies were considered in the country, and during short-term planning, it was planned that the existing knowledge and technology in universities and scientific and technical complexes of the country should be used. In addition, in areas requiring technology transfer from the other country, transferring and localizing technology was planned in a medium-term plan.

In domestic technologies, we could refer to research, existing facilities and equipment, upgrading and manufacturing new equipment in domestic research institutes, and establishing specialized centers. Each of these institutes has significant facilities in various fields such as reservoir studies, EOR, exploration, drilling, and exploitation, which can complete and upgrade equipment and capabilities of human resources as a specialized center providing services in the EOR/IOR and reviewing and solving its problems.

One of the sustainable achievements of the research was to create an EOR center. The main task of this center is to supervise applied, fundamental, and developmental research in the oil EOR. In this center, the facilities for manufacturing the required devices, research laboratories, and EOR studies will be provided, and by conducting field studies, suitable technology for field development will be chosen according to the current conditions. Moreover, by focusing on EOR studies in this specialized center,

field development will be faster, and if necessary, technology transfer and technology localization will be on the agenda.

Moreover, one of the outcomes is training and improving the capabilities of industry and university experts. In technology transfer, especially technology transfer from abroad, targeting is such that at the same time with technology transfer, the issue of training and empowerment of personnel is seriously considered so that in addition to localization of technology, there is no dependence on the foreign side as much as possible. Domestic experts, centers, and individuals involved in work from foreign universities during the project achieve this. In this regard, various training courses in reservoir engineering, operation, and management can be provided.

Nomenclature

CTE	Critical technology elements
EOR	Enhanced Oil Recovery
IOR	Improved oil recovery
NIOC	National Iranian Oil Company
TMP	Technology maturation plan
TRL	Technology readiness levels

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