

Identification and Prioritization of Obstacles and Platforms for Technology Transfer in Iran's Oil and Gas Industry under Economic and Technological Sanctions

*tarkan hosseini*¹

karim.hamdi^{2*}

*Hosein-vazifehdoust*³

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Abstract

This research has been conducted with the objective of identifying key obstacles and platforms for technology transfer in Iran's oil and gas industry under international sanctions and prioritizing them. The present study is of a mixed-method (qualitative-quantitative) type. In the qualitative phase, obstacles and platforms were identified through semi-structured interviews with experts and thematic analysis using MAXQDA software. In the quantitative phase, prioritization of factors was accomplished utilizing the fuzzy Delphi technique with the participation of 15 experts; accordingly, data were analyzed using triangular fuzzy numbers and the center of gravity method, and subsequently prioritized based on the definite mean of items in the second stage of questionnaire distribution. Findings indicated that the most important obstacles to technology transfer in Iran's oil and gas industry under economic sanctions are reduced foreign investment (0.95), non-conformity of domestic standards with global standards (0.946), and inability to develop necessary infrastructure (0.93). Furthermore, the most important platforms comprise comprehensive national technology development plans (0.95), digitalization of petroleum processes (0.95), and activities of research institutions and specialized universities (0.95). The research demonstrated that sanctions have exerted a multi-layered effect on technology transfer, and endogenous solutions based on digitalization, strengthening scientific institutions, and developing flexible national standards constitute the most efficient strategy under current conditions. A significant compensatory relationship was observed between obstacles and platforms, indicating the possibility of neutralizing external obstacles through internal solutions.

Keywords: Technology transfer, oil and gas industry, technological sanctions, fuzzy Delphi.

¹. PhD student, Department of Business Administration, Science and Research Branch, Islamic Azad University, Tehran, Iran. Email address: Tarkan.hosseini@iau.ac

². Associate Professor, PhD, Department of Business Administration, Science and Research Branch, Islamic Azad University, Tehran, Iran. Email address: k.hamdi@iau.ac.ir (**Corresponding Author**)

³. Associate Professor, PhD, Department of Business Administration, Science and Research Branch, Islamic Azad University, Tehran, Iran. Email address: H-vazifehdoust@iau.ac.ir

Introduction

Iran is a developing country possessing the world's fourth-largest oil reserves and second-largest natural gas reserves (Sadabadi et al., 2025). Success in the oil and gas industry, which serves as the principal axis of Iran's economy, depends not merely on adequate resources but also on precise planning, appropriate policies, investment in infrastructure, novel technologies, and creation of reliable export markets (Behboudi & Al Jalaiz, 2025). With the intensification of economic sanctions in recent years, the process of technology transfer to this industry has encountered unprecedented challenges. These sanctions, which intensified from 2012 onward, have not only limited access to novel technologies but have also disrupted the supply chain of equipment, production capacity, logistics, market access, and after-sales services (Taleghani & Sola, 2025). Economic sanctions have emerged as vital instruments of geopolitical strategy and exert significant consequences for global energy markets, innovation pathways, and transition to sustainable energy systems. When infrastructure is not transferred to a country, it leads to unaffordable access to clean fuels as well as modern and clean technologies. During sanction periods, export of energy equipment and transfer of infrastructure and technology services constitute the principal challenge for target countries and other global regions. Moreover, sanctions impede technological advancements (Moteng et al., 2023). Regarding Iran, these limitations have occurred precisely when the oil industry faces an urgent need for technological modernization. Iran's oil industry possesses relatively good technical and engineering capacity compared to other oil-producing countries in the Persian Gulf region; however, a substantial portion of development

activities in this industry is executed through foreign capital and technology, and a significant percentage of required equipment and facilities is procured from abroad (Fouroughi Nasab et al., 2022). Conversely, global developments in clean energy and environmental requirements have exerted compounded pressure on this industry for technological updating. Given that this sector confronts escalating pressure to improve safety, reduce costs, and minimize environmental impacts, digital transformation provides novel pathways to achieve these objectives (Dosumu et al., 2024).

Under these circumstances, maintaining and developing oil and gas production capacities as the principal source of national revenue and preventing widening of the technological gap with the global oil industry necessitate profound comprehension of technology transfer obstacles and identification of requisite platforms to overcome these challenges from a strategic perspective. Hence, the absence of comprehensive research simultaneously addressing identification of obstacles and requisite operational platforms under sanctions has created a conspicuous gap in the literature. Therefore, this research endeavors, with the objective of identifying and prioritizing obstacles and platforms for technology transfer in Iran's oil and gas industry under economic sanctions, to provide appropriate responses to the following questions:

First: What are the obstacles to technology transfer in Iran's oil and gas industry under economic sanctions?

Second: What are the requisite platforms for technology transfer in Iran's oil and gas industry under economic sanctions?

Third: How is the prioritization of obstacles to technology transfer in Iran's oil and gas industry under economic sanctions?

Fourth: What is the prioritization of requisite platforms for technology transfer in Iran's oil and gas industry under economic sanctions?

Research findings can serve as a guiding light to assist oil industry policymakers in formulating realistic technology transfer strategies and as an operational guide for managers of oil companies in confronting technological challenges.

Literature Review and Research Background

Technology in the Oil and Gas Industry

The oil and gas sector has significantly shaped the global economy for years; nevertheless, this industry confronts multiple obstacles such as oil price fluctuations, geopolitical unpredictability, and environmental concerns, thereby necessitating creative solutions to ensure its sustainable future. Experts seek to leverage the capacity of the Fourth Industrial Revolution, characterized by integration of advanced technologies such as Internet of Things (IoT), Big Data Analytics (BDA), Machine Learning (ML), Artificial Intelligence (AI), and automation in industrial processes, to address problems with prominent impacts on efficiency, safety, and environmental sustainability (Taifa et al., 2025). Specific examples demonstrate how businesses utilize technologies such as real-time data analytics, artificial intelligence, and automation to simplify operations, enhance efficiency, and achieve fundamental advancements in performance (Hazaa & Al Mubarak, 2025). For instance, despite the quality of materials used in pipeline construction and protective methods employed to reduce corrosion and degradation in pipes, pipelines remain susceptible to leakage, abrasion, and rupture due to various factors. To ensure pipe-

line safety, efficient Pipeline Leakage Monitoring Systems (PLMS) are required. PLMS exist as software packages. These hardware and software components detect potential leakage and sabotage before, during, and after occurrence and prior to loss of control (Taifa et al., 2025).

Technology Transfer

Technology transfer encompasses the transfer of equipment, machinery, tools, production facilities (any hardware), methods, processes, designs and plans (any software), knowledge of manufacturing and producing goods or providing services, maintenance and repair knowledge, management knowledge, and knowledge of renovation and development (technical knowledge), individually or concurrently, as components and categories of technology under consideration (Rahmani & Darvishi, 2024).

Technological Sanctions

Technological advancement is fundamentally guided by free exchange, communications, and fair competition. Limitations such as economic and technological sanctions may restrict the technological advancement of target countries. Technological sanctions are typically designed to limit technology transfer that potentially impedes the economic development of the target country. Another principal objective of technological sanctions, beyond non-economic considerations, is to restrain the technological advancement of target countries and preserve the technological dominance of the sanctioning country (Lo, 2025).

Research Background

Omokaro et al. (2025) demonstrate that sanctions disrupt energy supply chains, limiting target oil and gas countries' access to foreign investment, advanced technologies, and integration into global financial systems. Simultaneously, they have adopted adaptive responses including domestic innovation efforts, covert export methods, and new geopolitical alliances. Notably, sanctions have stimulated local innovation in certain areas, such as Iran's refining technologies and Venezuela's shadow fleet logistics. Fathalizadeh and Belhaj (2023) identified obstacles to technology transfer in the oil and gas industry within four categories: "lack of international communications," "inadequate project financing," "lack of technology management knowledge," and "inappropriate technology transfer methods." They stated that to counter technology transfer obstacles in the upstream sector, infrastructure such as research and technology centers, the role of technology transfer in upstream contracts, connections between educational and research centers with oil companies and contractors, and existing rewards in contracts related to technology transfer must be strengthened and highlighted. Varadarajan (2023) concluded that oil-producing countries lacking capital and technological infrastructure due to weak government support for research and development have suffered compared to oil-producing countries whose governments were committed to technology and advancement, and must possess political will and undertake preventive measures for their own technology development to overcome the technology gap. Jafari Toye and Noruzi (2024) state that long-term economic growth fundamentally depends on technology enhancement and

innovation, and despite Iran's extensive human and natural capacities, it still confronts structural, institutional, and international challenges in traversing this path. Hence, in their research they identified two principal obstacles to technology transfer in Iran's petrochemical industry: international sanctions (financial transaction limitations, difficulty enabling domestic companies' presence with licenses and equipment in global markets, non-cooperation of leading foreign (Western) companies with domestic companies) and power of global market orders (guidance and cooperation toward Middle Eastern countries' entry into production of primary and raw petrochemical products in line with global division of labor, creation of external markets for sale of Iran's primary petrochemical products). Rahmani and Darvishi (2024) also, referring to the necessity of technology development and transfer in oil-producing and developing countries, stated that technology transfer and development requires integrated and systematic management to determine the role of each technology domain actor and specify their level of benefit in the country's technology development. Scientific capacity building and technical skills for absorbing ideas and fully comprehending complexities inherent in imported novel technologies and methods of utilizing advanced tools and equipment related to these technologies are not only essential for developing oil-producing countries but also vital for indigenization and technological innovations and development and commercialization of these technologies.

Research Methodology

This research has been conducted with the objective of identifying and prioritizing key obstacles and platforms for technology transfer in Iran's oil and gas industry under

international sanctions. Therefore, the present research is of an applied type, and its results can be utilized in solving real problems and policies. The research is also descriptive-survey in terms of objective; methodologically, it employs a mixed (qualitative-quantitative) approach. In the qualitative section, thematic analysis methodology is utilized to identify items related to the research topic. Thematic analysis is a method for identifying, organizing, and offering systematic insight regarding patterns of meaning (themes) within a dataset. (1) Flexibility, (2) subjectivity and reflexivity, (3) theme development, (4) analytical process, and (5) diversity in theme analysis distinguish this methodology from other qualitative approaches (Kushnir, 2025). Regarding theoretical frameworks and questions in this research, semi-structured interviews with 16 experts-including managers and decision-makers in the oil and gas industry, professors and researchers in oil/gas and technology fields were conducted to identify concepts related to the research. Interviews were conducted with full observance of ethical considerations and obtaining interviewee consent; interview content and codes were approved by participants to preserve the principle of trustworthiness. In this phase, coding and analysis of findings were performed using MAXQDA software, identifying 6 main code categories comprising obstacles to technology transfer in Iran's oil and gas industry and similarly 6 main code categories comprising platforms for technology transfer in Iran's oil and gas industry under sanctions.

Furthermore, in the second phase of research implementation and for prioritization of codes identified in the qualitative phase, the Fuzzy Delphi Method (FDM) was employed. The Delphi technique and

its fuzzy variant are extensively utilized across various sectors, including industrial applications, to achieve expert consensus and identify priorities (Khorshidikia et al., 2025). The FDM enhances conventional Delphi techniques by incorporating fuzzy logic, enabling experts to express opinions using linguistic terms rather than precise numerical scales, thereby reducing ambiguity and increasing clarity. This method addresses unbalanced linguistic data, rendering it suitable for contexts requiring different levels of differentiation, and considers complex feedback systems to create stronger consensus free from subjectivity induced by a single observer. The FDM is more flexible than traditional Delphi methods and suitable for complex decision-making situations, providing a robust framework for expert consensus (Saiyed et al., 2025). In this method, questionnaires must first be distributed among experts. Accordingly, in this research a questionnaire with a 5-point Likert scale based on sub-codes obtained from the qualitative phase was prepared and distributed among 15 experts selected purposively.

Analysis of Research Findings

In this phase of research, following expert interviews, data were analyzed using MAXQDA software and main and sub-codes were extracted from interviews according to the thematic analysis approach. Table (1) displays obstacles to technology transfer in the oil and gas industry under sanctions.

Table 1- Obstacles to technology transfer in the oil and gas industry under sanctions

Main Components	Sub-components	Source
Legal and Regulatory Obstacles	Export restrictions on technologies (by sanctioning countries such as USA, European Union)	EX03, EX06, EX07
	Direct prohibitions on transfer of advanced technologies (in exploration, extraction, processing, and transportation of oil and gas domains)	EX03, EX12, EX14
	Impossibility of concluding international contracts with technology-oriented companies (due to fear of secondary sanctions)	EX05, EX07, EX09
Financial and Economic Obstacles	Limited access to international banking systems (SWIFT and dollar transactions for technology expense payments)	EX02, EX11
	Increased costs of technology transfer (due to need for intermediation)	EX01, EX11
	Reduced foreign investment in oil and gas projects due to sanction risk	EX01, EX08, EX12, EX16
Technical and Knowledge-Based Obstacles	Disruption of advanced technology supply chains (e.g., engineering software, intelligent drilling equipment, monitoring systems)	EX01, EX04, EX06, EX13
	Lack of access to technical updates and after-sales services	EX14
	Revocation of software licenses by foreign companies	EX02, EX07, EX15
Organizational and Managerial Obstacles	Weakness in domestic innovation structures and lack of synergy between research, development, and operations sectors	EX10
	Absence of comprehensive strategy regarding technology indigenization in oil companies under sanctions	EX10, EX11
Human Resource-Related Obstacles	Knowledge governance challenges in absorbing and reproducing technology	EX01
	Brain drain due to reduced advanced employment opportunities in the country	EX05, EX08
	Shortage of specialized personnel in novel technology domains (e.g., artificial intelligence, digitalization of oil fields)	EX08
	Limitations in access to international specialized training	EX03, EX06, EX14, EX15
Infrastructural Obstacles	Inability to develop necessary infrastructure for adoption of advanced technologies (e.g., industrial internet networks, digital platforms)	EX02, EX13, EX15
	Non-conformity of domestic standards with global technology standards	EX08, EX12

Table (2) displays requisite platforms for successful technology transfer in the oil and gas industry under economic sanctions.

Table 2- Necessary platforms for technology transfer in the oil and gas industry under sanctions

Main Components	Sub-components	Source
Policy and Strategic Platforms	Comprehensive national technology development plans	EX03, EX07, EX11, EX13, EX16
	Removal of domestic legal obstacles to international scientific-industrial cooperation with non-sanctioned countries	EX07, EX15
	Encouragement of technology substitution and strategic self-sufficiency policies	EX01, EX02, EX12
Institutional and Organizational Platforms	Formation of oil and gas knowledge-based networks	EX02, EX05, EX07, EX12, EX13
	Activities of research institutions and specialized universities (e.g., Petroleum University of Technology, Ministry of Petroleum research centers)	EX04, EX05, EX09, EX12, EX16
	Establishment of technology management units in oil companies for technology production	EX06, EX15
Financial and Incentive Platforms	Securing financial resources through technology development funds	EX08, EX10, EX12
	Tax exemptions and credit facilities for knowledge-based companies active in oil and gas domain	EX10, EX16
	Coordination between public and private sectors for joint investment in strategic technologies	EX04, EX13, EX14, EX16
Indirect International Platforms	Cooperation with third countries (e.g., China, Russia, India, Turkey) for technology intermediation	EX12
	Utilization of mechanisms such as scientific cooperation, international conferences, publications for technology transfer	EX02, EX05, EX06, EX07, EX12
	Development of reverse migration networks for indirect knowledge transfer	EX03, EX05, EX06, EX11, EX15
Technological and Digital Platforms	Development of domestic substitute software (e.g., reservoir simulation software, intelligent well monitoring)	EX07, EX09, EX10, EX11
	Digitalization of petroleum processes to enhance efficiency and reduce dependence on foreign technology	EX02, EX05, EX06, EX07, EX12, EX16
Human and Cultural Platforms	Strengthening innovation culture and risk acceptance in oil and gas industry organizations	EX01, EX05, EX07, EX09, EX15, EX16
	Continuous training of specialized personnel in emerging technology domains	EX04, EX11
	Encouragement of applied and project-oriented research in universities and research centers	EX14, EX16

Following determination of items and components related to obstacles and platforms from the qualitative section, it is necessary in the quantitative section of research to utilize the fuzzy Delphi method to determine priority and importance of each identified obstacle and platform from the qualitative section. In this phase, one question is designed for each code or sub-component,

which experts then answer. The number of selected experts in this phase is 15 individuals. Subsequently, linguistic values must be converted to triangular fuzzy numbers. For this purpose, triangular numbers are defined as values (l, m, u) ranging from very unimportant to very important according to Table 3.

Table 3 – Triangular fuzzy numbers for conversion of linguistic values in questionnaire with five-point scale

Linguistic Variable	Fuzzy Value	Triangular Fuzzy Number
Very Important (VH)	$\tilde{5}$	(0.75, 1, 1)
Important (H)	$\tilde{4}$	(0.5, 0.75, 1)
Medium (M)	$\tilde{3}$	(0.25, 0.5, 0.75)
Low Importance (L)	$\tilde{2}$	(0, 0.25, 0.5)
Very Low Importance (VL)	$\tilde{1}$	(0, 0, 0.25)

Furthermore, fuzzy mean must be measured for each variable of the research. Fuzzy mean is obtained from Equation (1) according to Hosseini and Soleymani (2025).

Equation(1)

$$F_{AGR} = \left(\frac{\sum l}{n}, \frac{\sum m}{n}, \frac{\sum u}{n} \right)$$

Subsequently, definite values are measured using the center of gravity method; this operation is termed defuzzification. According to Equation (2), the center of gravity method is utilized for classification of fuzzy weight $A_{ij} = (l_{ij}, m_{ij}, u_{ij})$ for each expert to convert it to a specific number for ranking fuzzy numbers (Bahadoran Baghbadorani et al., 2025).

Equation(2)

$$DF = ((l_{ij} + m_{ij} + u_{ij}) / 3)$$

Table (4) displays fuzzy mean and defuzzified values for themes related to

obstacles to technology transfer in the oil and gas industry under sanctions; this operation was performed with two rounds of questionnaire distribution.

Table 4 – Fuzzy mean and defuzzified values for themes related to obstacles

First Questionnaire Distribution Round				Variables	Second Questionnaire Distribution Round			
Defuzzified Value	Fuzzy Mean				Fuzzy Mean			Defuzzified Value
0.873	0.72	0.92	0.98	Export restrictions on technologies	0.74	0.94	0.99	0.89
0.840	0.68	0.88	0.96	Direct prohibitions on transfer of advanced technologies	0.70	0.90	0.97	0.857
0.830	0.67	0.87	0.95	Impossibility of concluding international contracts with technology-oriented companies	0.65	0.85	0.94	0.813
0.920	0.80	0.96	1.00	Limited access to international banking systems (SWIFT and dollar transactions)	0.82	0.97	1.00	0.93
0.857	0.70	0.90	0.97	Increased costs of technology transfer (due to need for intermediation)	0.72	0.91	0.98	0.87
0.943	0.85	0.98	1.00	Reduced foreign investment in oil and gas projects due to sanction risk	0.86	0.99	1.00	0.95
0.890	0.75	0.93	0.99	Disruption of advanced technology supply chains	0.77	0.94	0.99	0.90
0.773	0.60	0.80	0.92	Lack of access to technical updates and after-sales services	0.62	0.82	0.93	0.79
0.810	0.64	0.85	0.94	Revocation of software licenses by foreign companies	0.63	0.85	0.96	0.813
0.727	0.55	0.75	0.88	Weakness in domestic innovation structures and lack of synergy between R&D and operations	0.60	0.73	0.81	0.713
0.857	0.70	0.90	0.97	Absence of comprehensive strategy regarding technology indigenization in oil companies under sanctions	0.72	0.91	0.98	0.87
0.773	0.60	0.80	0.92	Knowledge governance challenges in absorbing and reproducing technology	0.59	0.83	0.91	0.776
0.890	0.75	0.93	0.99	Brain drain due to reduced advanced employment opportunities in the country	0.77	0.91	0.99	0.89
0.813	0.65	0.85	0.94	Shortage of specialized personnel in novel technology domains	0.62	0.87	0.92	0.803
0.857	0.70	0.90	0.97	Limitations in access to international specialized training	0.72	0.91	0.98	0.87
0.920	0.80	0.96	1.00	Inability to develop necessary infrastructure for adoption of advanced technologies	0.82	0.97	1.00	0.93
0.943	0.85	0.98	1.00	Non-conformity of domestic standards with global technology standards	0.84	1.00	1.00	0.946

Table (5) similarly displays fuzzy mean and defuzzified themes related to requisite platforms for technology

transfer in the oil and gas industry under sanctions; this operation was performed with two rounds of questionnaire distribution.

Table 5 – Fuzzy mean and defuzzified values for themes related to platforms

First Questionnaire Distribution Round				Variables	Second Questionnaire Distribution Round			
Defuzzified Value	Fuzzy Mean				Fuzzy Mean			Defuzzified Value
0.943	0.85	0.98	1.00	Comprehensive national technology development plans	0.86	0.99	1.00	0.95
0.857	0.70	0.90	0.97	Removal of domestic legal obstacles to international scientific-industrial cooperation with non-sanctioned countries	0.72	0.91	0.98	0.870
0.890	0.75	0.93	0.99	Encouragement of technology substitution and strategic self-sufficiency policies	0.77	0.94	0.99	0.90
0.920	0.80	0.96	1.00	Formation of oil and gas knowledge-based networks	0.82	0.97	1.00	0.93
0.943	0.85	0.98	1.00	Activities of research institutions and specialized universities	0.86	0.99	1.00	0.95
0.830	0.67	0.85	0.97	Establishment of technology management units in oil companies for technology production	0.65	0.85	0.94	0.813
0.857	0.70	0.90	0.97	Securing financial resources through technology development funds	0.72	0.91	0.98	0.87
0.890	0.75	0.93	0.99	Tax exemptions and credit facilities for knowledge-based companies active in oil and gas domain	0.77	0.94	0.99	0.90
0.930	0.80	0.97	1.00	Coordination between public and private sectors for joint investment in strategic technologies	0.80	0.96	1.00	0.92
0.793	0.60	0.85	0.93	Cooperation with third countries for technology intermediation	0.63	0.85	0.91	0.796
0.857	0.70	0.90	0.97	Utilization of mechanisms such as scientific cooperation, international conferences, publications for technology transfer	0.67	0.92	0.97	0.85
0.773	0.60	0.80	0.92	Development of reverse migration networks for indirect knowledge transfer	0.62	0.82	0.93	0.79
0.910	0.75	1.00	1.00	Development of domestic substitute software	0.75	1.00	1.00	0.91
0.943	0.85	0.98	1.00	Digitalization of petroleum processes to enhance efficiency and reduce dependence on foreign technology	0.86	0.99	1.00	0.95
0.890	0.75	0.93	0.99	Strengthening innovation culture and risk acceptance in oil and gas industry organizations	0.77	0.94	0.99	0.90
0.870	0.72	0.91	0.98	Continuous training of specialized personnel in emerging technology domains	0.70	0.90	0.97	0.95
0.813	0.65	0.85	0.94	Encouragement of applied and project-oriented research in universities and research centers	0.63	0.82	0.96	0.80

In the subsequent phase, the difference in means between the two measurement rounds is calculated; if the value exceeds 0.1, the variable must be eliminated. As Tables 6 and 7 demonstrate, the mean difference for all variables is

less than 0.1, indicating high consensus among experts; consequently, all identified components will be retained.

Table 6 – Mean difference of obstacles in two questionnaire distribution rounds

Component	Mean Round 1	Mean Round 2	Mean Difference
Export restrictions on technologies	0.873	0.89	0.017
Direct prohibitions on transfer of advanced technologies	0.840	0.857	0.017
Impossibility of concluding international contracts with technology-oriented companies	0.83	0.813	0.017
Limited access to international banking systems	0.92	0.93	0.010
Increased costs of technology transfer	0.857	0.87	0.013
Reduced foreign investment in oil and gas projects due to sanction risk	0.943	0.95	0.007
Disruption of advanced technology supply chains	0.89	0.90	0.010
Lack of access to technical updates and after-sales services	0.773	0.79	0.017
Revocation of software licenses by foreign companies	0.81	0.813	0.003
Weakness in domestic innovation structures and lack of synergy between R&D and operations	0.727	0.713	0.014
Absence of comprehensive strategy regarding technology indigenization	0.857	0.87	0.013
Knowledge governance challenges in absorbing and reproducing technology	0.773	0.776	0.003
Brain drain due to reduced advanced employment opportunities	0.89	0.89	0.000
Shortage of specialized personnel in novel technology domains	0.813	0.803	0.010
Limitations in access to international specialized training	0.857	0.87	0.013
Inability to develop necessary infrastructure for adoption of advanced technologies	0.92	0.93	0.010
Non-conformity of domestic standards with global technology standards	0.943	0.946	0.003

Table 7 – Mean difference of platform items in two questionnaire distribution rounds

Component	Mean Round 1	Mean Round 2	Mean Difference
Comprehensive national technology development plans	0.943	0.95	0.007
Removal of domestic legal obstacles to international scientific-industrial cooperation	0.857	0.870	0.013
Encouragement of technology substitution and strategic self-sufficiency policies	0.89	0.90	0.010
Formation of oil and gas knowledge-based networks	0.92	0.93	0.010
Activities of research institutions and specialized universities	0.943	0.95	0.007
Establishment of technology management units in oil companies	0.83	0.813	0.017
Securing financial resources through technology development funds	0.857	0.87	0.013
Tax exemptions and credit facilities for knowledge-based companies	0.89	0.90	0.010
Coordination between public and private sectors for joint investment	0.93	0.92	0.010
Cooperation with third countries for technology intermediation	0.793	0.796	0.003
Utilization of mechanisms such as scientific cooperation, conferences, publications	0.857	0.85	0.002
Development of reverse migration networks for indirect knowledge transfer	0.773	0.79	0.017
Development of domestic substitute software	0.91	0.91	0.000
Digitalization of petroleum processes	0.943	0.95	0.007
Strengthening innovation culture and risk acceptance	0.89	0.90	0.010
Continuous training of specialized personnel in emerging technology domains	0.87	0.95	0.080
Encouragement of applied and project-oriented research	0.813	0.80	0.013

In the final research phase, obstacles and platforms for technology transfer in the oil and gas industry under economic sanctions are ranked based on definite mean values

(from highest to lowest) in the second questionnaire distribution round. Table 8 displays this ranking.

Table 8 – Ranking of obstacles and platforms for technology transfer in oil and gas industry under sanctions

Rank	Mean	Obstacles	Rank	Mean
1	0.950	Reduced foreign investment in oil and gas projects due to sanction risk	1	0.950
2	0.946	Non-conformity of domestic standards with global technology standards	2	0.950
3	0.930	Inability to develop necessary infrastructure for adoption of advanced technologies	3	0.950
4	0.930	Limited access to international banking systems (SWIFT and dollar transactions)	4	0.950
5	0.900	Disruption of advanced technology supply chains (e.g., engineering software, intelligent drilling equipment)	5	0.930
6	0.890	Export restrictions on technologies (by sanctioning countries such as USA, EU)	6	0.920
7	0.890	Brain drain due to reduced advanced employment opportunities in the country	7	0.910
8	0.870	Limitations in access to international specialized training	8	0.900
9	0.870	Absence of comprehensive strategy regarding technology indigenization in oil companies under sanctions	9	0.900
10	0.870	Increased costs of technology transfer (due to need for intermediation)	10	0.900
11	0.857	Direct prohibitions on transfer of advanced technologies (in exploration, extraction, processing, transportation)	11	0.870
12	0.813	Impossibility of concluding international contracts with technology-oriented companies (due to fear of secondary sanctions)	12	0.870
13	0.813	Revocation of software licenses by foreign companies	13	0.850
14	0.803	Shortage of specialized personnel in novel technology domains (e.g., artificial intelligence, digitalization of oil fields)	14	0.813
15	0.790	Lack of access to technical updates and after-sales services	15	0.800
16	0.776	Knowledge governance challenges in absorbing and reproducing technology	16	0.796
17	0.713	Weakness in domestic innovation structures and lack of synergy between research, development, and operations sectors	17	0.790

Discussion and Conclusion

This research, employing a mixed-method (qualitative-quantitative) approach and utilizing the fuzzy Delphi technique, has successfully identified and prioritized obstacles and platforms for technology transfer in the oil and gas industry under sanctions. The research effectively demonstrated that sanctions have exerted multi-layered and intensifying effects on technology transfer. The research identified six principal categories of obstacles: legal-regulatory, financial-economic, technical-knowledge-based, organizational-managerial, human resources, and infrastructural. Research results indicate that the most important obstacle to technology transfer in Iran's oil and gas industry under sanctions is reduced foreign investment due to sanction risk with a definite mean of 0.95. This finding confirms that even with technology availability and domestic companies' willingness, absence of foreign investment functions as a key challenge. Limited access to international banking systems (0.93) can disrupt the technology transfer lifecycle. Priority of financial and investment obstacles over technical obstacles indicates that despite existing technical capacity, lack of financial resources constitutes the principal barrier to technology transfer under sanctions. Furthermore, non-conformity of domestic standards with global standards (0.946) and inability to develop necessary infrastructure (0.93) rank in subsequent positions, indicating a profound infrastructural and technical gap in this industry.

Conversely, and consistent with research findings, six principal categories of requisite platforms for technology transfer under sanctions include policy-strategic, institutional-organizational, financial-incentive, indirect international, technological-digital, and human-cultural platforms.

The most important identified platform is comprehensive national technology development plans with a mean of 0.95, emphasizing the necessity of macro-level and strategic planning at the national level. Digitalization of petroleum processes and activities of research institutions and specialized universities also with the same mean demonstrate the pivotal role of digital transformation and scientific institutions in transitioning from technological dependence. Overall, results indicate that domestic solutions (such as development of substitute software, digitalization, and strengthening scientific institutions) can partially neutralize external obstacles (such as supply chain disruption and limited access to international banks), and while external obstacles (investment, standards, banking access) rank at the forefront, domestic platforms (national planning, digitalization, scientific institutions) can serve as pathways to exit technological deadlock.

The following practical recommendations are presented across four strategic levels:

1. Macro/National Level

At the national level, it is essential to develop flexible national standards compatible with sanctions conditions while maintaining the capacity for future alignment with international standards. Additionally, establishing a National Oil and Gas Innovation Fund can significantly support domestic technology development through dedicated financial resources. Concurrently, efforts should be made to build robust trade relationships with countries facing similar constraints and to develop extensive commercial networks and international cooperation particularly with Iran's neighboring countries as a strategic pathway to mitigate the adverse effects of sanctions.

2. Organizational Level

At the organizational level, oil companies should establish dedicated technology development centers to ensure low-risk technological advancement while maintaining compliance with international regulations and standards. Furthermore, mandating oil companies to formulate comprehensive technology localization plans will channel organizational efforts toward constructive technology advancement and development. It is also recommended to design and implement inter-university educational programs both domestic and international that focus on strengthening infrastructure, advancing technology development, and facilitating technology transfer mechanisms.

3. Technological Level

At the technological level, targeted investment in digital infrastructure is critical, including industrial internet systems, data-driven platforms, and digital twins of oil and gas fields. Equally important is the development of domestic alternative software, prioritized according to a "technology criticality index" (e.g., reservoir simulation systems, intelligent well monitoring technologies) to address the most vital operational needs first.

4. Human Resources Level

At the human resources level, implementing a comprehensive national program for attracting and retaining elite talent is imperative to counter brain drain and leverage diaspora expertise. Reforming the higher education system in oil and gas disciplines through curriculum modernization, integration of emerging technologies (AI, IoT, data analytics), and establishment of specialized training centers represents a crucial step toward cultivating a professional, future-ready workforce.

Given that this research's results depend on temporal conditions and sanction structure against Iran, the findings may not be generalizable to other countries; therefore, researchers are recommended in future studies to examine obstacles and platforms for technology transfer in countries under sanction conditions to further indigenize the technology transfer process. Furthermore, this research focused on the oil and gas industry domain, and its results are not generalizable to other industries; hence, future researchers are recommended to examine sanction effects on technology transfer across various industries.

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