Petroleum Business Review, Vol. 7, No. 4, pp. 59–73, October 2023

Systematic and Structural Analysis of the Innovation System of Iran's Oil Industry

Ali Yousefi[1*], Naser Bagherimoghadam[2], and Mahdi Sahafzadeh[1]

[1]Assistant Professor, Department of Management and Accounting, Farabi Campus, Tehran University, Qom, Iran
[2]Ph.D. Candidate, Department of Technology and Innovation Policy Group, a National Research Institute for Science Policy (NRISP), Tehran, Iran

Highlights

- Summarizing the findings section, relying on the systemic components of the technological innovation system presented, and considering previous studies determined that such a study for the country's oil industry based on the system technological innovation with structural–functional analysis had not been done so far.
- This work comprehensively classified the actors and institutions active in this field in the mentioned framework and determined their relations at a macro level.
- All five components of the actors' technological innovation system discussed the current situation's functions, communications, and challenges.
- Identifying and redefining the functions and relationship of intermediary institutions with other elements of the oil innovation system are some suggestions that can be considered after this study.
- Strengthening many actors in the components of knowledge and technology supply and knowledge structure will help improve the existing system. It is suggested that functional challenges and challenges related to the duties of each actor should also be studied and researched.
- Organizational frameworks and systemic procedures and methods of this system should also be investigated in future research.

Received: August 16, 2022; *revised:* August 16, 2022; *accepted:* May 20, 2023

Abstract

In this descriptive qualitative research with a case study research strategy, the Iranian oil industry innovation system adopts an in-depth structural and functional approach (systemic approach) and its natural context from the perspective of the participants studied. Based on a theoretical framework that includes five systemic components of the innovation system, actors and relationships between them have been identified. Multiple information sources (interviews, observations, and document analysis) ensure the structure's validity. Furthermore, previous theories have been used as the initial theoretical framework of the research to achieve external validity. The absorption and development of strategic knowledge and technologies of the oil industry were introduced as the system's primary function, and three sub-functions were identified. Identifying 29 existing structural and functional challenges from the perspective of experts has complemented the understanding of this system. Finally, policy proposals are presented.

Keywords: Innovation System, Oil Industry, Systematic Approach, Technology and Innovation Development.

How to cite this article
Yousefi, A, Bagherimoghadam, N, Sahafzadeh, M., Systematic and Structural Analysis of Innovation System of Iran's Oil Industry, Petroleum Business Review, Vol. 7, No. 4, p. 60–75, 2023. DOI: 10.22050/pbr.2023.356326.1275

[*] Corresponding author:
Email: ali.yusefi@ut.ac.ir

1. Introduction

Over the past few decades, global investment in the oil and gas sector has led to an upward trend in technology in the oil and gas industry. The emergence of new phenomena such as three-dimensional and four-dimensional seismography, horizontal and multilateral drilling, and other new techniques reduce errors and costs and improve productivity and production of oil and gas fields. The advanced technologies of the oil industry are often available to large transnational corporations, and using these technologies is difficult for oil-rich developing countries due to the scarcity of technology in these countries. Utilization of technologies requires a framework and processes in which research, development, technology, and innovation procedures are defined and codified in different ways.

On the other hand, the feedback of major companies and other stakeholders in research and technology of the oil industry indicates the existence of many challenges in the process of research and technology and innovation of the oil industry and the need to review it based on existing structures, functions, and methods of research and technology in the oil industry. The study conducted in this field has been minimal, mainly within the country's executive organs to meet the daily needs. There are also extensive but scattered efforts to develop technology and innovation in different parts of the country; however, many do not achieve the desired result due to the lack of clear technological development procedures.

Accordingly, for analyzing these issues at the level of the oil industry, it seems that a comprehensive structural and systematic analysis of the elements at the industry level, which are actors and, in some way, responsible for this task, can be helpful. This study aims to provide a structural framework and, simultaneously, a technology development and innovation system in the oil industry. By systematically examining this issue, the macro process of technology development and innovation in the Iranian oil industry in the form of a technological innovation system based on observation of the current situation, data analysis of thematic literature, experimental background, and opinions of experts in the field is presented. The literature related to this research originates from the subject of innovation systems. The subject of innovation systems is the heart of the content of this research, and the researchers sought to use the approach of innovation systems and their types in explaining the technological innovation framework of the oil industry. Researchers believe this will help shape the processes and relationships between the components of the desired framework. A brief overview of these issues is provided below to explain these cases.

Innovation is a central concept considered one of the key achievements of business in the present century. The study of innovation systems began in 1841 and has continued its evolution until now (Riahi and Ghazi Nouri). With the advent of the innovation system approach, there has been a strong emphasis on national innovation systems (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Among the various innovation systems, some researchers have focused on technological innovation systems (Carlsson and Jacobson, 2004; Carlsson et al., 2002). According to Source and Hekrt (2009), the technological innovation system, despite having standard features with other innovation system approaches, has two distinguishing features: the first emphasizes the role of economic viability, and the second seriously emphasizes the system's dynamics (Suurs and Hekkert, 2009).

Technological innovation systems can be used to analyze technological change and have a primary function. AdQuist (2004) considers the pursuit of innovation processes, or in other words, the development, dissemination, and application of technology in practice, as the primary function of innovation systems. Researchers have identified various tasks in the first level of the system to study the extent to which the primary function of the system is realized. Therefore, the system's functions can be considered sub-functions of its primary function (Bagheri Moghadam et al., 2012).

If viewed systematically and systematically, five main components are considered systematic in a technological innovation system. If the system is viewed from a higher level, all the structural factors combined to form an extensive network can be considered. This vast network is a cohesive whole that forms the system's configuration. These five components are the government structure, the supply side structure, the demand side structure, the knowledge structure, and the relationship structure of these components (Suurs R.A., 2009).

The supply side covers all the structures involved in producing and supplying products and technological knowledge. These usually include industries as well as research institutes.

The demand side is related to the use of technology. In the form of actors, this structure includes end customers, firms, and governments.

The knowledge structure consists of all actors, institutions, and technologies that support other subsystems by producing, evaluating, and transferring knowledge.

The government subsystem includes structural factors related to the policy area. In the form of actors, this subsystem includes ministries, other government agencies, states, and municipalities.

Finally, the intermediate structure includes structural factors that support relationships and interactions between all subsystems (Suurs R.A., 2009).

In examining the components of the innovation system on a case-by-case basis, we can refer to the work of Ansari and Taybi (2013) about research and technology organizations in the national innovation system of Iran and the work of Bandarian (2019) about providing a model for technology development and commercialization in research and technology organizations. Karimi (2017) aimed to determine the role of science and technology centers in the development of the oil industry by focusing on the literature on the national innovation system and counting the actions and activities of the innovation system in the oil industry and related institutions.

In the relationship between industry, academia, and government in various sectors, referring to our work published in 2012, the country's electricity can be studied and analyzed, and the function and role of research management institutions in the electricity industry innovation system can be determined.

In the field of pathology of the innovation system at the industry level in structural and functional dimensions, we can also refer to the articles of Heirani et al. (2014 and 2018) and Mohammadi and Zolfagharzadeh (2020). One of the most relevant works is a paper discussing the pathology and current status of the system, innovation, industry, oil, and Iran using functional-institutional analysis (Payende and Mortazavi, 2020). In this article, the institutional mapping of Iran's oil industry and the functions of the innovation system are the basis of the analysis. Finally, the institution–function matrix is drawn and analyzed using the above two categories.

According to the studies conducted in previous research, it is observed that despite examining different angles of innovation systems at the industry level, none of them has explained the exact dimensions of the technological innovation system of Iran's oil industry by mentioning its functions and actors. Moreover, the relationships between these actors at different levels have not been determined. Some studies have addressed only limited aspects of this system and have not considered structural and functional analysis of the oil industry innovation system. In the functional–structural analysis approach, which is the newest approach in the methods of technological innovation system analysis, researchers believe that based on the relationship and interaction of functions and structural factors, the cause of weakness or strength of each system function, structural factors related to that function (Markard et al., 2012; Truffer et al., 2009), and the structural components of the technological innovation system affect

the performance (Suurs and Hekkert, 2009). The present study seeks to determine these dimensions by considering a basic framework derived from a technological innovation system with a systems approach. In this article, researchers aim to use this system model in the structural and functional analysis of the country's oil industry innovation system. For this purpose, the systematic framework of the technological innovation system presented by the source has been used as a theoretical framework of the research (Figure 1), which is mentioned in the methodology section.

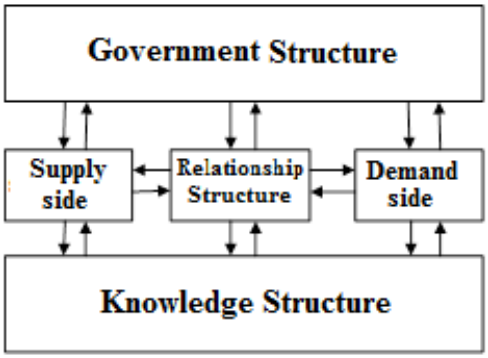

Figure 1

The theoretical framework of research (Suurs R.A., 2009)

This model has not been used for structural and functional analysis of the country's oil industry. Numerous articles have addressed this issue from different angles. Some have explained one or more components of the innovation system, and some have analyzed the system for other industries, as reviewed above.

2. Methodology

This research is qualitative in terms of approach because the researcher wants to reveal the nature of the truth through research in the real world. The researcher has an inner position. The sampling method and the selection of subjects are non-random and purposeful, and all data are also displayed as text units. Qualitative methods are used in data analysis, and the research design is spontaneous and emerging (Creswell, 2009). The present research is a case study in terms of research strategy. It intends to study the technological innovation system of Iran's oil industry by adopting an in-depth structural and systemic approach and its natural context. The case study method, with the potential to delve into a particular case, allows the researcher to understand the dynamics of the case under study (Eisenhardt K.M., 1989, 2007).

According to Yin R.K. (2014) classification, this study is complementary (technological innovation system of Iran's oil industry) with several units of analysis (government structure, supply side structure, demand side structure, knowledge structure, and the structure of relationships of these components). The process modeled and used in this research is the case study process and includes the following steps (Yin R.K., 2014): Development of research design, data collection, and data analysis. In this study, the previous theories have been used as the initial theoretical framework to ensure the validity of multiple information sources (interviews, observations, and document analysis) and critical and knowledgeable people to review the case study report and obtain external validity. To achieve an acceptable level of reliability, the researcher has provided an accurate report of the focus of the study and the data collection platform. In addition, case study protocols have been used for this purpose, and a case study database has been created.

Case studies require collecting data from various sources and using different methods such as interviews, observation, and analysis of documents. In this research, a total of 19 in-depth and semi-structured interviews have been conducted with National Iranian Oil Companies, National Iranian Gas Company, the University of Petroleum Industry, and Petroleum Industry Research Institute, and with a group of university experts in the field of technology management active in the energy sector. The organizational status of the interviewees and the date and duration of the interviews are listed in Table 1. In this study, case study protocols have been used and exploited; this means that the interviews had specific features and instructions, and appropriate and purposeful questions were prepared for the interviewed experts and were the basis of the interview sessions.

Table 1

Information about the interviewees and the date and duration of the interviews

Row	Organizational status	Date	Duration	Individual meeting	Group meeting
1	Director General of Research and Technology of the Ministry of Oil	15-Oct	90 min	✓	✓
2	Head of Research and Technology Management of National Iranian Oil Company	17-Oct	90 min	✓	✓
3	Research and technology management of the National Iranian Oil Refining and Distribution Company	19-Oct	90 min	✓	✓
4	Department of Technology, Petrochemical Research and Technology Company	15-Oct	90 min	✓	✓
5	Head of Research Institute for Overdraft from Oil and Gas Reservoirs	18-Oct	60 min	✓	✓
6	President of the University of Petroleum Industry	27-Sep	120 min		✓
7	Technology Policy Department of National Iranian Gas Company	27-Sep	120 min		✓
8	Vice Chancellor for Research and Technology, University of Petroleum Industry	27-Sep	120 min		✓
9	Deputy of Technology and International Relations of Petroleum Industry Research Institute	27-Sep	120 min		✓
10	Department of Technology and Innovation, Petroleum Industry Research Institute	27-Sep	120 min		✓
11	Deputy of Planning of Petroleum Industry Research Institute	27-Sep	120 min		✓
12	Faculty of the Scientific Policy Research Center of the country	29-Nov	120 min	✓	
13	Head of Research Institute for New Technologies Studies, Scientific and Industrial Research Organization of Iran	1-Dec	60 min	✓	
14	Faculty of the Scientific Policy Research Center of the country	25-Nov	60 min		✓
15	Faculty of Research Institute of Basic Sciences and Technology of Shahid Beheshti University	25-Nov	120 min		✓
16	Faculty of the Sharif University of Technology	25-Nov	120 min	✓	✓

Row	Organizational status	Date	Duration	Individual meeting	Group meeting
17	Faculty of the Sharif University of Technology	25-Nov	120 min		✓
18	Faculty of the Sharif University of Technology	25-Nov	120 min		✓

In addition, several documents, including lecture files of managers of companies and government organizations; strategic and long-term plans; performance reports; project progress reports; technology roadmaps; national and sector strategic documents related to the oil and gas industry; other national documents; and news and announcements on the websites of National Iranian Oil Companies, National Iranian Gas Company, Petroleum Industry Research Institute, University of Petroleum Industry, and other significant subsidiaries in the oil industry, have been studied.

The following steps were taken to analyze the data. First, the data were organized and prepared for analysis: interviews and lectures were implemented, and the text of the interviews was ready. Then, different types of collected documents were studied and recorded. Third, the textual data obtained from the interviews and the analysis of the papers were thoroughly researched. Fourth, based on the systemic framework of the technological innovation system, evidence and examples were found concerning each of the five components of the technological innovation system, through which the five structural elements of the technological innovation system in the Iranian oil industry were found. An attempt was made to give meaning to the data obtained from the research and theoretical framework.

This research uses a one-section analysis technique to study the data obtained from interviews, field observations, and various documents. This method helps the researcher identify the roles and relationships in question in a given period and a given community, as well as events and happenings around a particular subject that occurred in that period. Cross-sectional studies are observational and are known as descriptive research (Yin R.K., 2014.)

3. Findings

In this section, first, the actors of each of the five components of the theoretical framework of the research are identified in terms of structure and actors. Then, the relationship between the components is examined. Next, this system's main functions and sub-functions are identified, and the actors of each are introduced. After that, the challenges of the current technological innovation system of the oil industry have been identified and summarized separately by components and communications based on experts' opinions.

The first system component studied in the technological innovation system of the oil industry is the demand side of knowledge-based technologies. The demand side is related to the use of technology. In the form of actors, this structure includes end customers, firms, and governments. In this position, the first and most critical structural actors observed are the subsidiaries of the oil industry's national oil, gas, petrochemical, refining, and distribution companies. In these companies, which manage the primary operations of the oil industry, the main demand for technology is observed. Operating companies, which are somehow contracting oil subsidiaries, are the second category of technology applicants. These include general contractors, operations and service companies, and engineering and construction companies. The third category is some domestic technology and knowledge-based companies that cooperate with similar foreign companies and obtain the interfacial technologies needed to develop the final technological products. Finally, the fourth category of small and medium-sized

Iranian companies is related to the first and second category companies seeking technologies they need in their service and production activities to provide for the oil industry.

Regarding the supply side of technology regarding the essential knowledge technologies offered to the oil industry, the first category of domestic and foreign universities and research institutes develop the fundamental knowledge technologies required by the oil industry, which usually base their research results on the required technologies. The second category is international oil companies, which can transfer some of their technologies to domestic applicant companies by carrying out oil super projects in the country. The third category of foreign knowledge-based companies is the development of unique and case technologies. Usually, the variety of these technologies is high, and they are needed in many places in the industry.

One of the most critical components of the technological innovation system is the structure of the relationship or intermediary institutions. The role of these institutions is mainly to mediate between supply and demand. This section includes organizations that somehow turn research from the supply side into products the demand side needs. Oil industry research and development institutes have this role. These institutions operate privately or are governmental agencies affiliated with the government of industry (Government Research Institute). Specifically, from the interviewed experts' perspective, the Petroleum Industry Research Institute can play this role.

The fourth component of this system is the government structure or policy-making and decision-making institutions at the level of the oil industry. The government subsystem includes structural factors related to the policy area. This subsystem contains ministries and other government agencies in the form of actors. According to experts and by studying the available documents (including letters, regulations, and instructions issued at the industry level), the leading players in this oil industry sector are the Ministry of Oil and the National Iranian Oil, Gas, Petrochemical, Distribution, and Refining Companies. Further, some policies and decisions are made at the level of subsidiaries of the leading companies.

Finally, the fifth component of this system is the knowledge structure required for technology development and innovation. The knowledge structure consists of all actors, institutions, and technologies that support other subsystems by producing, evaluating, and transmitting knowledge. Universities and other organizations in the education system fall into this subsystem. The University of Petroleum Industry, the Research Institute of Petroleum Industry, and other universities in the country related to the oil industry fall into this category. The sum of the actors mentioned above in this system, which most experts approved, is listed in Table 2.

Table 2

Actors in the oil industry research and technology system

Type of actors	**Title**	
Actors in the government (structure government)	✓ Oil Ministry	✓ National Iranian companies (oil, gas, etc).
Cast supply side structure	✓ International oil companies (IOCS) such as Total, Shell and... ✓ Domestic and foreign knowledge-based companies	✓ Foreign contracting companies ✓ Domestic and Foreign Small and Medium enterprises (SMEs) ✓ Domestic and foreign universities
Cast demand side structure	✓ Subsidiaries of National Oil ✓ and Gas Companies ✓ Iranian contractor companies such as Oyek,	✓ Domestic knowledge-based companies ✓ Domestic Small and Medium Enterprises (SMEs)

Type of actors	Title	
Cast mediator structure	Pasargard oil and gas and... ✓ Research and Development Institutions (RTI) ✓ General, such as research institutes affiliated with universities	✓ Government Research and Development Institutions (GRI) such as the Petroleum Industry Research Institute
Cast knowledge structure	✓ Iranian universities	✓ Iranian Research Centers

In the field of communication between the five components of the technological innovation system of the oil industry, the primary communication established between the university and the oil industry has been through research contracts and technology development with the sector's employer. Based on the study of existing documents and experts' comments in the interview sessions, oil contracts signed between the Ministry of Oil and universities can be divided into three categories. The first period of oil contracts was in overdraft from oil and gas fields, through which some universities activated oil institutes. The second series of contracts signed between the Ministry of Oil and the country's universities is focused on the downstream field to improve the consumption process in the high-consumption sectors of the industry. These contracts focus on the production and creation of processes and the improvement of methods such as the production of methanol, urea, ammonia, gas desalination, and part of oil refining. A university is selected as the central executor and partner university in these contracts. The third series of research contracts is in the field of exploration.

In recent years, the Ministry of Petroleum has made some investments in some universities, such as the Sharif University of Technology, Amirkabir University of Technology, Shiraz University, Sahand University of Technology, and the University of Tehran, in some formats such as equipping laboratories related to overharvesting and sending some professors to study advanced courses abroad.

Regarding the relationship between the university and the oil industry, according to experts in this field, there are challenges; one of the most critical challenges in this field is the difference between the level of maturity of universities and the oil industry and, consequently, the lack of proper translation of sector needs at the university level. Therefore, the existence of an interfacial structure with the presence of mediating institutions helps solve this central challenge.

One of the questions raised in the expert interview sessions was the challenges in the current innovation system. Based on the opinions provided by the experts, a list of challenges and their frequency was compiled into a table. Some of the questions raised in this regard were focused on challenges related to the structure of the technological innovation system or the relationship between the actors. Therefore, in Table 3, the structural–communication challenges of the technological innovation system of the oil industry are mentioned following each component of the system and the communications of that component, according to the frequency of each existing challenge.

Table 3

Structural–communication challenges of the existing innovation system of the oil industry

Row	Component	Challenges counted	Abundance
1	Demand side	The process of approving technology development projects in the current system is long.	8

Row	Component	Challenges counted	Abundance
2		There is no research portfolio definition. There is no technology or research portfolio.	2
3		The organizational structure of technology applicants is not based on an innovation system and needs to be reformed.	7
4		The budget structure of applicants and employers is not defined.	7
5		The difference between the level of maturity of universities and the oil industry and therefore the lack of proper translation of the needs of industry in the university	6
6	Knowledge structure	In relation to commercialization, neither the appropriate organizational structure nor the appropriate executive levers are defined	2
7		Intellectual property infrastructure is not provided like in other parts of the country.	3
8		Lack of necessary platforms for commercialization of technology, including the development of innovation centers	5
9		The Petroleum Industry Research Institute practically does not play the role of mediator between the supplier and the technology applicant, and has become a mere supplier.	6
10	Intermediate structure	Instead of managing and directing research and technology development among suppliers, the Petroleum Industry Research Institute itself conducts technology development research.	4
11		There is virtually no facilitation.	2
12		Lack of demand-driven products and services provided by universities, research centers and knowledge-based	1
13	Supply side	Multiplicity of presenters and different levels of presenters	1
14		The relationship between technology and scientific poles is one-way.	1
15	Government structure	Research topics are bottom-up.	1
16		There is no regulation of research.	3
17	Component	The border of technology development policy between the Ministry of Oil and the main companies is not clear.	2

In addition to identifying the challenges of the current situation, to better identify the technological innovation system of the oil industry, it is necessary to explain the main activities in the form of the innovation system. For this purpose, first, the main functions of this system were identified using studies in the literature of technological innovation systems, the results of documents in the field of comparative

studies of oil industry innovation systems in other countries, especially Norway and Brazil, and the results of expert opinions interviewed in the format of expert meetings and a panel of experts. Finally, the absorption and development of strategic knowledge and technologies of the oil industry as the macro function of the oil industry innovation system were approved by experts.

According to the experts in the relevant panels, the following main functions appropriate to the type of technologies (emerging strategic technologies, mature strategic technologies, and challenging non-strategic mature technologies) and sub-functions for the technological innovation system of the oil industry can be considered (see Table 4). The first sub-function is focused on the technologies that need to be provided to the oil industry in the future. The activities and measures required for their development are mainly formed by the university and the industry. Under the second function, mature technologies are currently used in the industry. Still, knowledge does not exist in the industry and is used only by a user in this category. The primary way to achieve these technologies is through large transnational oil companies with technology. The third sub-function also addresses explicitly the day-to-day challenges of the industry.

Table 4

Main functions and sub-functions of the technological innovation system of the oil industry

Main function	Sub-function
Absorption and development of strategic knowledge and technologies in the oil industry	Development and commercialization of future (emerging) technologies in the oil industry
	Development of mature strategic technologies in the oil industry
	Solve the technological challenges of the oil industry at various levels

Following the proposed sub-functions, active actors in each function were identified. Table 5 lists the results of studies conducted by researchers by studying the available documents, field observations, and experts' opinions, and finally, confirming the results in the panel of experts.

Table 5

Institutions and actors related to the sub-functions of the technological innovation system of the oil industry

Function	Sub-function	Actors	
Absorption and development of strategic knowledge and technologies in the oil industry	Development and commercialization of future (emerging) technologies in the oil industry	• Research and technology management of principal companies/subsidiaries • Research and technology council of the leading company • Deputy of engineering, research and technology • Domestic and foreign universities and research centers • Policy Council of the Ministry of Oil • Research institutes/testing centers	• Research centers/development companies and domestic and foreign knowledge-based companies of financial funds • Domestic and foreign industrial companies • Oil industry research centers, universities, and research centers

Function	Sub-function	Actors	
	Development of mature strategic technologies in the oil industry	• Research and technology management of principal companies/subsidiaries • Research and technology council of significant companies • Deputy of engineering, research and technology • Executors of technology transfer and development	• International oil companies • Research institutes/testing centers • General contracting companies • Operations and service companies • Engineering and construction companies
	Solve the technological challenges of the oil industry at various levels	• Research and technology management of principal companies/subsidiaries • Deputy of engineering, research and technology • Oil industry research centers, universities, research centers, and engineering consulting companies	• Domestic and foreign knowledge-based companies • General contracting companies • Operations and service companies • Engineering and construction companies

As with the structural part, one of the questions raised in interviews with experts is the functional challenges in the existing technological innovation system. Based on the opinions provided by the experts, a list of challenges was compiled, and the frequency of the points raised in Table 6 was compiled.

Table 6

Functional challenges of the existing oil industry innovation system

Row	Challenges encountered	Abundance
1	The mismatch between authority and accountability in the innovation system	11
2	There is no excellent supervision and great support; research policy is not correlated in terms of management and supervision;	7
3	The position of universities, institutions, hubs, and the like in the macro science and technology system is not well defined;	5
5	There is no intellectual property and knowledge management;	4
6	Policy-making is not done correctly (what resources, what people, and when);	4
7	Lack of attention to market policy versus technology	4
8	It is not right to separate industrial research institutes from universities and research institutes of the Ministry of Science, and they should not be competitors;	3
9	Priorities are undefined;	2
10	There is no vision or long-term plan;	2
11	It is unclear whether one should seek to exploit or transfer technology;	1
12	Macro research priorities are undefined;	1
13	R&D units do staff work, and research work is neglected;	1

According to Table 6, the main functional challenges in this sector are focused on the oil governance structure. According to experts, different institutions' definitions, roles, and functions, as well as their role in the innovation system, have not been determined.

4. Conclusions

Summarizing the materials presented in the findings section, relying on the systemic components of the technological innovation system presented in the theoretical framework of the research, and considering the studies conducted in previous research determined that such a study for the country's oil industry based on the system technological innovation with structural–functional analysis had not been done so far. This research has comprehensively classified the actors and institutions active in this field in the mentioned framework and has determined their relations at the macro level. Further, all stages of this research have been based on experts' opinions.

Special attention is paid to the relations between knowledge institutions such as universities and research centers with the governing companies of the oil industry, both directly and through intermediary institutions. On the other hand, knowledge-based companies and small and medium companies active in the industry that produce the knowledge and technologies required by the industry have been seen in this system. The governance structure in the Ministry of Oil and the national oil and gas companies are considered policymakers and regulators according to the systemic components in this system.

The functions, communications, and challenges of the current situation were discussed in all five components of the actors' technological innovation system. The suppliers of technology and innovation are mainly universities, research institutes, and domestic and foreign knowledge-based companies. However, foreign universities and companies in the oil industry are minimal, and they do not establish unique relations with other components.

The leading state-owned companies and subsidiaries of the oil industry are in the demand component. Contractors, engineering companies, and service providers are also among the applicants for technological products and services. Lack of accurate identification of technological needs is one of the significant challenges in this area. Reforming the structures of state-owned companies in the research and technology sector, as well as reforming research and technology procedures and processes within companies, will help solve the challenges in this field and strengthen the role of actors in the technological innovation system of the oil industry.

There are severe infrastructural weaknesses and challenges in the knowledge structures component. Universities and research centers have provided the knowledge base to some extent for developing oil industry technology. However, many soft and hard infrastructure problems, including the issue of intellectual property in the soft field and laboratory and workshop infrastructure in the hard field, can be considered by government institutions to complete and strengthen the technology development chain in this system. Establishing innovation centers and science and technology parks as a knowledge infrastructure for technology development is another proposed policy.

In the component of the government structure, which is mainly played by the Ministry of Oil and the national oil and gas companies, implementing correct policies in the field of research and technology will promote the industrial innovation system. One of the essential policies of the supply side, especially foreign suppliers, is using market policy in exchange for technology. This issue can also be seen as an appendix to technology development in oil production and operations contracts. Defining primary research and technology projects and utilizing the capacity of universities in this regard are other proposed policies.

Finally, in the component of intermediary structures, in the opinion of researchers and with the approval of some experts, strengthening the role of the Research Institute of Petroleum Industry and other intermediary institutions is very important, and the relationship between the research institute and universities and applicant companies is suggested to be improved. It is recommended that the research institute should manage and lead technology research and development to become a suitable link between other components of the innovation system.

Identifying and redefining the functions and relationship of intermediary institutions with other elements of the oil innovation system is one of the suggestions that can be considered after this study. Addressing the identified challenges also requires a detailed and at the same time systematic design of the innovation system. Moreover, strengthening many actors in the components of knowledge and technology supply and knowledge structure will help improve the existing system. Given that the identification of existing challenges has been based on the structures and relationships of actors and institutions of the innovation system, it is suggested that functional challenges and challenges related to the duties of each actor should also be studied and researched. In addition, considering that implementing this framework requires partial design and process at the level of the oil industry, it is suggested that organizational frameworks and systemic procedures and methods of this system be investigated in future research.

Nomenclature

GRI	Government Research and Development Institutions
IOCS	International oil companies
RTI	Research and Development Institutions
SMEs	Small and Medium enterprises

References

Ansari, R., Tayebi, H. (2013). A Study and Explanation of Research and Technology Organizations in the National Innovation System of Iran, Case Study: University of Jihad. Technology Growth, Specialized Quarterly of Parks and Growth Centers, 37, 13–21.

Azad, S. M., Ghodsypour, S. H. (2018). Modeling the dynamics of technological innovation system in the oil and gas sector. Kybernetes, 47(4), 771–800.

Azevedo Ferreira, M. L., Rezende Ramos, R. (2015). Making University-Industry Technological Partnerships Work: A Case Study in the Brazilian Oil Innovation System. Journal of Technology Management and Innovation, 10(1), 173–187.

Bagheri Moghadam, N., Hosseini, S.H., Sahafzadeh, M. (2012). An analysis of the industry–government–university relationships in Iran's power sector: A benchmarking approach, Technology in Society, Elsevier, 34(4), 284–294.

Bagheri Moghadam, N., Mousavi Dorcheh, S.M., Nasiri, M., Moallemi, E. (2012). Motors of Innovation, a Novel Approach for Analyzing Technological Innovation Systems. National Research Institute for Science Policy. 4(1), 283. (In Persian).

Bandarian, R., Bandarian, M. (2019). Effective model of technology development in research and technology organizations. Journal of Industry and University, 17 (5), 27–38.

Breschi, S. and Malerba, F. (1997). Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries. Systems of innovation: Technologies, institutions and organizations, 130–156.

Chung, C. (2018). Technological innovation systems in multi-level governance frameworks: The case of Taiwan's biodiesel innovation system (1997–2016). Journal of Cleaner Production, 184, 130–142.

Creswell, J. W. (2009). Research Design (Qualitative, Quantitative, and Mixed Methods Approach). Third Edition, Sage Publication.

Edquist, C. (1997). Systems of Innovation: Technologies, Institutions, and Organizations. London/Washington: Frances Pinter.

Edquist, C. and Chaminade, C. (2006). Industrial policy from a systems-of-innovation perspective, EIB PAPERS, 11(1), 108–132.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of Management Review, 14(4), 532–550.

Eisenhardt, K. M., and Graebner, M. E. (2007). Theory Building from Cases: Opportunities and Challenges. Academy of Management Journal, 50(1), 25–32.

Eliassy, M., Et al. (2013). The role and position of defense science and technology in national power and providing a model for its use in civilian applications. Strategic Research Center of the General Staff of the Armed Forces.

Fagerberg, J., Mowery, D. C., Verspagen, B. (2009). The evolution of Norway's national innovation system. Science and Public Policy, 36(6), 431–444.

Ghazinoory, S., Nasri, S., Ameri, F., Montazer, G. A., Shayan, A. (2020). Why do we need a "Problem-oriented Innovation System (PIS)" for solving macro-level societal problems? Technological Forecasting and Social Change, 150, 119–149.

Hekkert, M. P., Negro, S., Heimeriks, G. and Harmsen, R. (2011). Technological Innovation System Analysis a Manual for Analysts, Utrecht University, The Netherlands: 1–15.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlman, S. and Smits, R. E.(2007). Functions of innovation systems: A new approach for analyzing technological change. Technological forecasting and social change, 74(4), 413–432.

Kostopoulos, k., Papalexandris, A., Papachroni, M. and Ioannou, G. (2011). Absorptive capacity, innovation, and financial performance .Journal of Business Research, 64 (12), 1335–1343.

Malerba, F. (2002). Sectoral systems of innovation and production. Research Policy,31(2), 247–264 .

Payende, R., Mortazavi, S. (2020). Pathology of Iranian Oil Industry Innovation System Based on Functional–Institutional Analysis. Quarterly Journal of Progress Research: Systems and Strategies, 2 (2), 127–155.

Riahi, P., Ghazi Nouri, S. (2014). Introduction to Innovation System (broad approach). University Publication Center. Tehran

Shakeri, O., Razavi, M.R., Eliasy, M. (2021). Analysis of the technological transition strategy of simultaneous production of electricity and heat in Iran. Quarterly Journal of Strategic Studies in the Oil and Energy Industry. 13 (50). 1–22.

Skoczkowski, T., Verdolini, E., Bielecki, S., Kochański, M., Korczak, K., and Węglarz, A. (2020). Technology Innovation System analysis of decarbonization options in the EU steel industry. Energy, 118688.

Suurs, R. A. (2009). Motors of sustainable innovation: Towards a theory on the dynamics of technological innovation systems, Dissertation, Utrecht University: The Netherlands.

Suurs, R. A. and Hekkert, M. P. (2009). Cumulative causation in the formation of a technological innovation system: The case of biofuels in the Netherlands. Technological Forecasting and Social Change, 76(8), 1003–1020.

Wild, G. et al., (2007). The innovation potential of bulk nanostructured materials. Advanced Engineering Materials, 9(7), 527–533.

Yin, R. K. (2014). Case Study Research: Design and Methods. 5th Edition. Sage Publication.