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Choosing a Suitable Method of Acquiring Logging Technology of Oil and Gas Wells in Iran: (A Case Study of National Iranian Drilling Company)

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Abstract

Drilling industry and its technical services are among the complex and advanced technology-based industries in the cycle of oil exploration and production. In this regard, the logging services role as one of the pillars of technical services is very important due to technological complexity and the importance of the results in the evaluation of oil and gas reservoirs. The complexity had caused small and medium companies in Iran not to be able to produce logging equipment by themselves due to financial and scientific constraints. Through the review of the articles and books written on this subject, this research has studied the factors affecting success in technology acquisition and then has categorized them in five dimensions as technological, technical, market, strategic, and financial factors. Next, through exploratory interviews with experts and theme analysis, the factors having the greatest impact on the acquisition of logging equipment technology have been identified and their opinion on various proposed methods in scientific resources for the acquisition of technology have been obtained. Several published methods have been reviewed; during interviews, some major effective characteristics were introduced by the experts, which could not satisfy existing methods or some principal dimensions were ignored. The results of the research and the case study of National Iranian Drilling Company show that the managed innovation network is the most appropriate method for the acquisition of the above mentioned technology for the National Iranian Drilling Company.

Keywords: Technology, Technology Acquisition, Logging Industry, Thematic Analysis, National Iranian Drilling Company

1. Introduction

According to Vision 1404, the first place of technology in the region, the second place of oil production in the Organization of the Petroleum Exporting Countries (OPEC), and the third gas producer in the world are drawn in the optimal image of oil and gas industry. This is while most of the oil production reservoirs of our country are in the second half of their life, and their production has been declining. The increasing trend of domestic consumption also affects exports and foreign exchange earnings of the country greatly.

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According to the oil and gas industry value chain, new dynamic technologies in the areas of detailed petro-physical assessment of exploration wells, planning for development wells, updated and detailed acquired data from reservoirs, preserved production, and security of the data acquisition of oil and gas fields are extremely important. Restrictions on access to new equipment and getting help from foreign companies to acquire information about oil and gas reservoirs can lead to the withdrawal of valuable information on the reservoirs from the country. In addition to leaking of large amounts of currency, this matter can also affect political orientation in the international bodies such as OPEC. The interesting point is that if foreign companies shut down the projects for different reasons such as insecurity in the region, or irrationally increase the cost of their services, oil production will be facing a crisis.

Technologies available in the oil and gas industry have always been a part of high-tech industries. Drilling industry, due to tough environmental conditions and exposure to unpredictable events during drilling, is one of the industries that have taken the highest advantage of technology in relation to time management, financial resource management, safety standards observance, and keeping oil production ceiling. The identification of the parameters of the earth layers and oil and gas reservoirs at the depths of more than 3,000 meters is performed by logging services in very poor conditions and at high temperatures and pressures in the presence of corrosive gases based on a diverse range of technological equipment and by observing the highest standards. For the detection of hydrocarbon layers between layers of the earth, the outputs resulting from logging need to be very accurate and sensitive. Failure to use appropriate technology to obtain this information can waste huge costs of initial exploration and drilling and deprive the country of access to new resources. The importance and value of logging services are also tangible in the comparison of revenue ratio of home services for wellhead technical services. Among the 15 main services, logging services alone, have allocated more than 25% of technical service revenues to themselves bases on cost analyses at NIDC. The average cost of drilling a well is about 150 million Euros in Iran (NIDC E-Bulletin, Nov 2009) and it can be said through the experience that about 10% of the costs are allocated to logging services.

A look at the history and life of more than one hundred years of exploration and production of oil in Iran emphasizes the fact that an acceptable level of localization and technology acquisition in this industry has not been achieved yet. The diversity of technical knowledge and a high level of reliability expected from products, on the one hand, and the lack of infrastructures and validation references, on the other hand, have had a significant impact on the dullness of the technology acquisition process.

In the evaluation and selection of technology acquisition method, it should be tried to meet all the goals of the organization in relation to the use of technology, and technology-related risks must also be taken into account. According to the above-mentioned limitations, technology assessment in this industry is largely based on personal experience, and little research has been conducted on technology acquisition method in the logging industry. This matter has created a major challenge for the decision makers who have to make appropriate decisions for the survival of the organization and the development of competitive advantages and who also have to make reasonable decisions in relation to choosing an appropriate technology acquisition method and its localization.

Companies that are active in this field are not capable of producing logging equipment by themselves because of the extension of the sciences applied to the equipment and the constraints of the available resources. Therefore, technological collaboration has always been considered by such companies as a way to use the knowledge of other companies and institutions to achieve the desired product. In addition, different models are expressed in literature for technological cooperation between organizations and companies each of which has its own advantages and disadvantages.

Choosing a suitable model of technology transfer as a sensitive and noteworthy process has always

been noticed and emphasized by planners and managers of organizations and companies. This study will answer the question that through the given multiplicity technology acquisition methods, which one is suitable for the acquisition of logging technology of oil and gas wells for the acquisition of logging technology of oil and gas wells. To answer this question, a qualitative research method, based on in-depth interviews with experts and the analysis of the theme is used.

Accordingly, after reviewing the literature and research methods, the factors affecting technology acquisition process are identified and classified. Then, through interviews and the analysis of the findings, some parameters will be introduced to choose the method of technology acquisition, which can be significant for the company for choosing a technological collaboration method. With regard to the characteristics of the desired technology, to the organization receiving it, and to the core parameters that are identified, the appropriate model of technological cooperation for the acquisition of logging equipment technology will be introduced through the case study of the National Iranian Drilling Company (NIDC).

2. Literature review

Technology acquisition is a process in which the selected technologies of the organization are acquired and provided for the organization to be used. It is in fact a process that begins by selecting a technology in the previous step and ends by acquiring technology using different methods of technology acquisition.

Technology acquisition is divided into three steps: scanning technology (including identification of potential technologies), choosing technology (technology assessment based on decision criterion), and internalizing technology, which is considered as the talent and capability of technology performance. Therefore, the technology acquisition process can be considered as the process whose input is appropriately selected technology and whose output is appropriately acquired technology (Figure 3). As displayed in Figure 3, the selection of appropriate method of technology acquisition is very important.

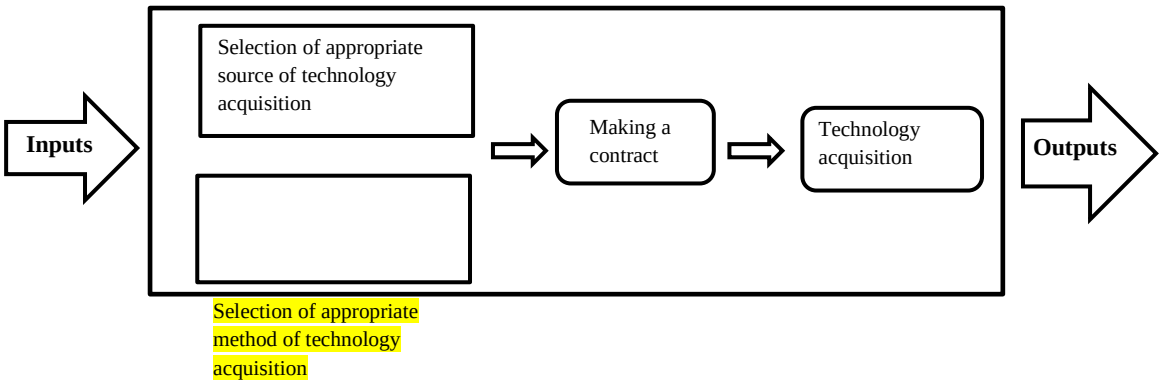

Figure 1
Technology acquisition system.

Technology can usually be achieved via three main approaches (Chiesa, 2001; Ford, 1988; Chatterjee, 1996) as follows:

- Internal research and development (internal technology acquisition);
- Technological cooperation;
- Purchase of technology (technology transfer);

In order to choose each one of these methods, it is necessary to identify and analyze the factors affecting technology acquisition. Chiesa analyzed the factors such as the time of development, preservation, learning, cost of development, familiarity, and technical risk and summarized their effects on each of the above three methods according to the following table. In this table, three stars show the most appropriate selection and one star indicates the lowest proportion to achieve the goal.

Table 1
Factors affecting making decision on the kind of technology acquisition.

Factors	Kinds of acquisition		
	Make	Cooperate	Buy
Development time	*	**	***
Preservation	***	**	*
Learning	**	***	*
Development cost	*	**	؟
Familiarity and technical risk	*	**	***

Given the major acquisition approaches, each technology requires a special acquisition method; the review of literature in this field emphasizes various methods of technology acquisition, some of which will be described and explained in the following section (see Figure 2).

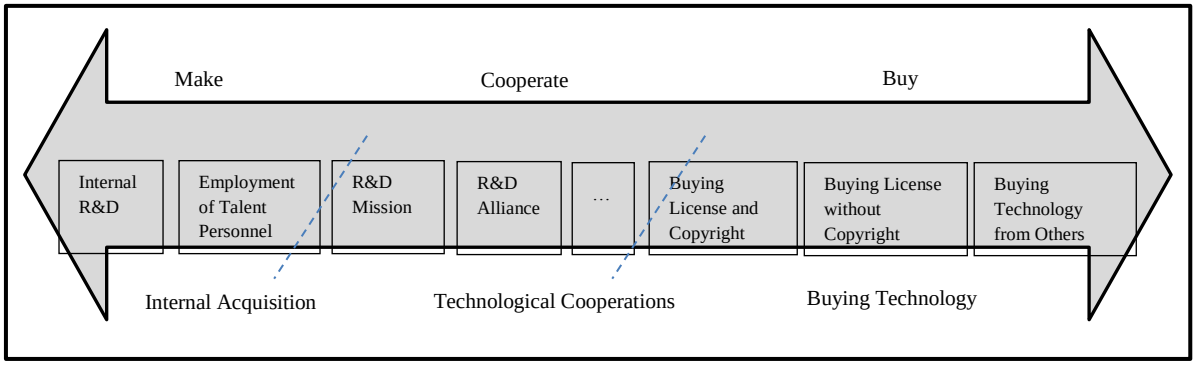

Figure 2
A variety of approaches and technology acquisition methods.

As can be seen, technology acquisition methods, depending on the type of technology and the conditions of the recipient and sender, are different and sometimes very diverse; the license agreement (Hemmert, 2004), acquisition (Arasti, 2008), strategic alliances (Chiesa, 1998), consortium (Nakamura and Adagiri, 2005), networking (Rycroft, 2003), joint venture (Ford, 1988), and spin off (Chiesa, 1998) can be referred to as some common examples.

2.1. Technology acquisition models

Each of the different technology acquisition methods, due to the diversity of approaches to achieve the technology, is emphasized in selecting appropriate methods in the literature of technology management, and several models have been proposed for this purpose. For example, the models offered by Tidd et al., Afva, Khalil, Robert and Barry, Ford, and Gilbert can be referred to.

Each of these models has dealt with the issue from a particular perspective and has provided the factors influencing the choice of method. Examining the features of logging technology and NIDC as the technology acquirer indicates that Ford Model is more compatible with the subject of the research than the other models. Therefore, this model was considered as the original framework and according to the findings of the study, some changes were made to it. This model is briefly described in the following.

Ford model

The factors considered in this decision making model as an appropriate way to achieve technology are:

- The relative ability of organization in the desired technology;
- The necessity of quick access to the desired technology;
- The necessity of technology ownership within the organization;
- Technology positions in the life cycle curve;
- Competitive (strategic) effects of technology;

As shown in Table 2, the ways offered by the model are a combination of technology transfer and internal development.

Table 2
Decision making matrix on technology acquisition method (Ford model).

Criterion / Acquisition method	Relative ability of firms in technology	The necessity of quick access to technology	The necessity of technology ownership within the organization	The effect of technology competition	Technology life cycle
Internal development	High	Lowest	Highest	Outstanding (critical)	Emersion
Creating joint business entity		Low			
Outsourcing research and development		Low			
Buying copyright		High	Lowest		
Buying technology product	Low	Highest	Completely unnecessary		

Chiesa model

Some factors considered in this decision making model about an appropriate technology acquisition method are as follows:

- Control over activities;
- Control over results;
- Risk;
- Startup time and costs;

Robert &and Berry model†

† Edition according to 4th advice of the reviewer

This model is not only associated to the selection of the suitable methods to transfer technology, but also attends general methods of achieving technology, including endogenous development. In this model, different strategies of obtaining technology in order to start a modern technology are studied. The amount of the familiarity of company with market on the one hand and familiarity with technology on the other hand are two main factors for decision making about the suitable method of achieving technology, which is considered as a base in this model. These two factors are classified as:

- There is fully identified base technology in the company. Fully identified base market is the current market of the company.
- Modern and identified technology: Technology has not previously existed in the company, but there was awareness about it.
- Unknown and modern technology: technology has not existed previously and is unknown.
- Modern and unknown market: there has not been a market for technology product by the present time and should be created by the company, or market should be previously existed, but there is not enough information about it in the company.

Table 3
Chiesa model.

Organizational and managerial implications	Managerially integrated acquisition	Managerially autonomous acquisition	Mergers	Joint ventures (collectively managed)	Equity consortia (single side managed	Minority equity	Alliance (collectively managed alliance)	Non-equity consortia (individually managed alliance)	Negotiated outsourcing	Research contracts/research funding (autonomous outsourcing)
Impact on the firms resources	High									low
Time horizon	←									
Control over activities	←									
Control over results	←									
Risk	←									
Startup time and costs	←									
Reversibility	Low									high

Gilbert's model

The technology transfer methods are divided into 4 classes:

- Inactive methods: in which receiver obtains the intended technology as an inactive body under a special condition like a turnkey method;
- Cooperation methods: in which technology transferee and transferor play active roles like providing a common business unit;
- Anti-competition methods: in which the required technology is acquired with the satisfaction of technology owner similar to industrial espionage or adverse engineering;
- General methods: in which the required knowledge or skill is obtained through participating in training periods, seminars, visiting expeditions etc.;

Two main factors of the tendency and ability of technology receiver to supply the requirements of technology owner and the control of technology owner in the mode of using technology by the receiver have fundamental roles in the selection of the above methods.

As mentioned, one of the most important barriers in the decision making process about the selection of the technology transfer projects is lack of a suitable model which can satisfy the used condition. In this section, it is tried to discuss the properties of the above model using a modern pattern in order to achieve the used model in the research text.

Based on conducted researches, acquiring technology for high-tech and multidisciplinary technologies in harsh environment especially in oil and gas industries has not reached any evidence locally. This kind of technology exclusively belongs to few multinational companies, so previous attempts on this matter are very rare worldwide. Similar models and published methods have been focused on conventional industries with a limited variety of knowledge and complexity. Furthermore, localization parameters are considered in this research.

3. Research method

The main objective of this study is to provide a strategic and local approach toward the acquisition of logging equipment technology of oil and gas wells. After studying different references, in order to achieve the parameters and local components, exploratory research method was employed. In this regard, at the first stage of the research, by using interviews with experts the main cores of logging technology acquisition were identified. All the interviews were recorded and an attempt was made to conduct individual interviews. By analyzing the theme, the main factors of logging technology assessment in Iran were encoded and classified.

Thematic analysis is a method of analyzing, determining, and expressing patterns (themes) within the data. This method, at its minimum, organizes and describes the data in detail, but it can go further and interpret different aspects of the research topic. Qualitative approaches are very diverse, complicated, and elegant, and theme analysis should be considered as a basic technique for qualitative analysis. Theme analysis process begins when the analyst considers meaningful patterns and topics which are of potential interest. The analysis includes a continuous sweep between data collection and the summary of the encoded data and the analysis of the created data. Analytical writing starts from the first phase. Theme analysis is a recursive process, in which there is a back-and-forth movement between the stages. In addition, theme analysis is a process which is performed over time (Clark and Brawn, 2006)[‡]. The following flow diagram (Figure 3) shows the processing steps based on Miles and Humberman model (1994, p.12).

To explore the vital criteria and to identify the main factors of logging technology acquisition, non-random samples consisting of sixteen subjects were examined, and the most critical factors were identified using the factors identified in the previous step consistent with the theme analysis. It is noteworthy that among the interviews, fourteen of them have been used, and it was to the extent that, according to the researchers, the identified categories had reached a saturation point (Locke, 2003)[§]. It should be noted that the research population included a number of experts of well logging, R & D, marketing, engineering, and planning departments of the NIDC. The interviewees had at least 10 years of experience in the field of drilling and logging technologies. Interviewers were graduated from well-known universities in geology, petroleum, and electronics engineering. They were in charge of strategic or executive decisions. According to the researcher's perception, for the easier understanding

[‡] Edition according to 3rd advice of the reviewer
[§] Edition according to a part of 1st advice of the reviewer

of the results of the interviews, they were classified into two whole scientific experts and administrative experts. The education levels of interviews were from B.S. to Ph.D., although the majority of which had a master's degree.

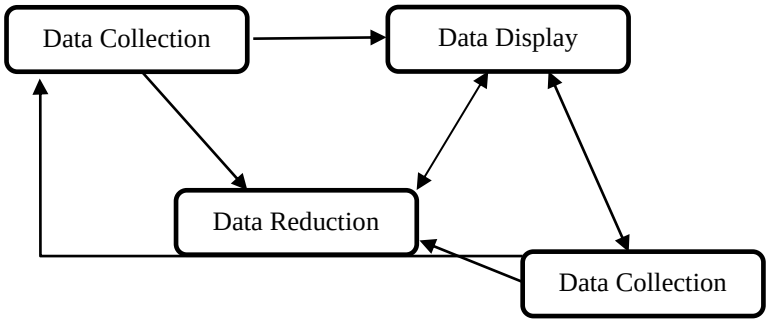

Figure 3
Components of data analysis in the interactive model of Miles and Humberman.

The mean age of subjects in this part of the study was 40 years. Due to the nature of drilling and logging industry, the employment of women with operational experience is very limited, so the research population was only composed of men. In each interview, the same general questions were used, and it then continued with specific questions (derived from the responses of those interviewed). The approximate time for each interview was about 60 minutes, and the important data in the course of the interviews were transcribed so that the information obtained in the interview could be ready to be analyzed and the spoken interview process could be developed as an integrated document. Then, the data were analyzed and integrated using theme analysis.

The steps used in this analysis to analyze the themes according to Brawn and Clark methodology (2006)[**] are as follows:

Step 1 preparation and familiarity with data: before analysis, the data were arranged to facilitate analyzing. The interviews were transcribed in this step and efforts were made to organize the data based on common concepts.

Step 2 creating initial codes: after arranging, studying, and becoming familiar with the data, the initial codes of the date were created. These codes identify one characteristic of the data that is interesting to the researchers.

Step 3 searching themes: in this stage, different codes were classified in the form of potential themes and all the summaries of the encoded data were arranged in the form of specified themes.

Step 4 creation of meaning and concepts: in this stage, researchers behaved with more freedom and beyond code classifications, and they emphasized the whole data; a comprehensive analysis of all the interviews was obtained.

4. Data analysis

4.1. Identification and classification of factors affecting technology acquisition process

There are many parameters and criteria for selecting an appropriate method of technological collaboration, which have always made the managers face problems in selecting the right method of

[**] Steps of analyzing replay to a part of 1st advice of the reviewer

technology transfer. Here are some of the relevant parameters presented in various references along with some of the data obtained in the interviews.

The classification presented in the research has put together the parameters which are conceptually close to the desired group, and it has offered a comprehensive classification. In this classification, the introduced models have been emphasized, and it has been tried to express the discretely-discussed parameters and criteria affecting technology transfer method as a coherent table. This was performed by classifying the parameters into five categories, including knowledge of technology, technical issues, market, strategic, and financial parameters. In interviews, some categories were conceptually close to each other, but they were outlined as independent factors in the classification table. This issue has been considered in the sum of concepts. In addition to analyzing the introduced parameters in some sources during the interviews, some new criteria were introduced by the interviewees.

Accordingly, after analyzing all the interviews base on Brawn and Clark methodology††, the importance of the discussed parameters was introduced in five groups with different importance levels, namely very high, high, medium, low, and very low.

Table 4
Introduction and classification of affective factors.

Importance level stated in the interviews	Reference	Criteria	Label	Class
Very high	Chu, 2009	Learning potential	TF1	Technological factors
Medium	Ford, 1998; Chiesa and Manzini, 1998	Technology life cycle	TF2	
Medium	Chiesa and Manzini, 1998; Skardon, 2011	Ability to protect technology	TF3	
Medium	Chiesa and Manzini, 1998; Robert and Berry, 1985	Familiarity with technology and market	TF4	
Medium	Skardon, 2011; Rogerio et al., 2007; Corsaro et al., 2012; Rampersad et al., 2010; Albers et al., 2013; Tidd et al., 2001	Relative ability of organizations in the desired technology	TF5	
High	Karamipour, A., Jolly, D., and Bolly, V. (2012)	Complexity of the technology and the possibility of imitation and copying	TF6	
High	Dickinson et al., 2001; Heidenberger and Stammer, 1999; Abdi et al., 2008; Baqeri Moqadam et al., 2008	Ability of the organization to update technology-related knowledge	TF7	
Medium	Heidenberger and Stammer, 1999; Karamipour, A., Jolly, D., and Bolly, V. (2012); Abdi et al., 2008	Previous knowledge of organization about the desired technology	TF8	

†† Edition according to a part of 1st advice of the reviewer

Importance level stated in the interviews	Reference	Criteria	Label	Class
Low	Ansari, M., Zare, A., 2007	Usage after the technology life	TF9	
Medium	Karamipour, A., Jolly, D., and Bolly, V. (2012)	Technology potential in development and promotion	TF10	
Medium	Dickinson et al., 2001; Hiedenberger and Stammer, 1999; Chu, 2009	Technology capacity	TF11	
High	Chan et al., 2000; Chu, 2009; Jiang, 2011	Service quality	TC1	
Very high	Chan et al., 2000; Chu, 2009; Behboodi Asl et al., 2012	Modification capabilities (flexibility)	TC2	
Very high	Henriksen et al., 1999; Traynor, 1999; Jamali and Hashemi, 2011	Technical reliability (risk)	TC3	
High	Research findings	Repair needs	TC4	
Medium	Research findings	Required degree of localization	TC5	Technical factors
Low	Research findings	Ease of implementation and management	TC6	
Medium	Research findings	Level of management capabilities and limitations	TC7	
High	Ansari, M., Zare, A., 2007	Technology compatibility with operational requirements	TC8	
Medium	Research findings	Shelf life (depreciation time)	TC9	
High	Ansari, M., Zare, A., 2007	Repair needs	TC10	
Very high	Research findings	Need for special resources and expertise within the company	TC11	
Medium	Karamipour, A., Jolly, D., and Bolly, V. 2012	Competitors inability to use the desired technology	MF1	
Low	Baqeri Moqadam et al., 2008; Karamipour, A., Jolly, D., and Bolly, V. 2012	Range of technology applications	MF2	
High	Linton et al., 2002; Tabatabaeian et al., 2008	Technology novelty based on life cycle	MF3	
High	Farnoodi, 2008	Support for the companies using technology	MF4	Market factors
Medium	Karamipour, A., Jolly, D., and Bolly, V. (2012)	Exclusive use of the desired technology	MF5	
High	Khalil, 2000; Karamipour, A., Jolly, D., and Bolly, V. (2012)	Market share achieved through the use of technology	MF6	
Medium	Karamipour, A., Jolly, D., and Bolly, V. (2012)	Threat of alternative technologies	MF7	
Medium	Tidd et al., 2001	Competitive effect of technology	MF8	
High	Tidd et al., 2001, Tidd and	Market access	MF9	

Importance level stated in the interviews	Reference	Criteria	Label	Class
High	Isamimoto, 2002; Skardon, 2011; Rogerio et al., 2007 Research findings	Available market size	MF10	
High	Hsu et al.,2010, Jiang, 2011	Organization maturity to use the desired technology	EF1	
High	Farnoodi, 2008; Farhangi et al., 2010	Governmental and legal supports	EF2	
High	Karamipour, A., Jolly, D., and Bolly, V. (2012)	Technology association with organization business	EF3	
High	Dickinson et al., 2001; Khalil, 2000	Technology alignment with the strategy and goals of the organization	EF4	
Medium		Technology security coefficient	EF5	
High	Behboodi Asl et al., 2012	Collaboration of technology supplier in consulting and training	EF6	
Very low	Baqeri Moqadam et al., 2008; Tabatabaeian et al., 2008; Khalil, 2000	Environmental protection	EF7	
Very low	Ansari, M., Zare, A., 2007	Dangerous effects of technology's end of life	EF8	
Medium	Research findings	Level of commitments	EF9	
High	Kaufmann et al., 2003; Rogerio et al., 2007; Yongping et al., 2011; Tidd et al., 2001; Tidd and Isamimoto, 2002	Knowledge meeting	EF10	Strategic factors
Medium	Tidd et al., 2001; Tidd and Isamimoto, 2002	Enterprise culture	EF11	
High	Tidd et al., 2001	Enterprise strategy	EF12	
Medium	Chiesa and Manzini, 1998	Size of company and fleet	EF13	
Medium	Skardon, 2011; Chiesa and Manzini, 1998	Ability to define the terms of cooperation	EF14	
Very high	Tidd et al., 2001; Ford, 1988; Tidd and Isamimoto, 2002	Necessity of quick access to the desired technology (development time)	EF15	
High	Tidd et al., 2001; Ford, 1988; Tidd and Isamimoto, 2002	Reference country	EF16	
High	Tidd et al., 2001; Tidd and Isamimoto, 2002	Type of time period	EF17	
High	Ford, 1998	Dependence on technology	EF18	
Very high	Lee, 1998	Control over the use of technology and mastery of technology ownership	EF19	

Importance level stated in the interviews	Reference	Criteria	Label	Class
Very high	Research findings	Control over results	EF20	
Medium	Chiesa and Manzini, 1998	How to contact with company	EF21	
Very high	Ansari, M., Zare, A., 2007	Development of entrepreneurship in country	EF22	
Very high	Ansari, M., Zare, A., 2007	Impact on reinsurance (increasing technological capability at the national level)	EF23	
Very high	Research findings	Control over activities	EF24	
Very high	Research findings	Range of acquirable technologies	EF25	
Medium	Tabatabaeian et al., 2008; Sue et al., 2010	Value of technology equipment	FF1	Financial factors
High	Baqeri Moqadam et al., 2008	Costs of research and development	FF2	
High	Baqeri Moqadam et al., 2008	Costs of implementation	FF3	
High	Jamali and Hashemi, 2911; Behboodi Asl et al., 2012	Costs of repairs and maintenance	FF4	
Very high	Abdi et al., 2008; Karamipour, A., Jolly, D., and Bolly, V. (2012)	Effective and economic benefits, return on investment	FF5	

Given that all technology transfer models cannot be applied to an organization, and this matter requires the review of strategies and goals of the organization and its capabilities, in this study, after the interview and determining the status and importance of the parameters of the above table, eleven key parameters in total were identified[‡‡]. The analysis of the results based on Likert scale of the interviews shows that the following factors have the greatest impact on the selection of appropriate methods of technology acquisition. According to Likert scale, we can assign average weight to each level (as example 1, 3, 5, 7, and 9 for five levels). In our case study, we can assign 9 for absolute internal technology development and 1 for absolute purchase; Likert scales are arbitrary. The value assigned to a Likert item has no objective numerical basis, either in terms of measure theory or scale. As the final analysis based on an average weight from Table 4, we introduce Table 5.

Table 5
Weighted mean of affective factors.

No.	Description	Normalized weighted factors
1	Need special resources and expertise within the company	8.5
2	Cost	13
3	Technical reliability (risk)	10
4	Development time and ability to modify	11
5	Mastery of technology ownership	8.7
6	Control over the results	13
7	Control over the activities	9.7
8	Absorption of knowledge within the company or the ability to learn	8.6

‡‡ Edition according to 2nd advice of the reviewer

9	Range of acquirable technologies	8.7
10	Increase of technological capability at the national level	8.8

4.2. Possible methods of logging technology acquisition

In addition to getting the opinions of the interviewees for the identification of effective factors, the most appropriate method of technology acquisition with regard to the introduced methods in scientific sources was emphasized. For the identification of methods, the interviewees' opinions were taken in two steps: first, their suggestions and second, their opinions about the suggested method(s) in scientific sources such as internal research and development or internal acquisition of technology; domestic and foreign technological cooperation; and the purchase or transfer of technology were implemented and arranged based on the highest frequencies.

Using the results of the above analyses, imaginable methods to acquire logging industry technologies were introduced to NIDC as follows:

- Internal research and development (Internal R & D): in this method, a research unit is deployed within NIDC and designs and develops the desired technology.
- Purchase or transfer of technology: in this method, a company or research center outside NIDC, under a turnkey contract, designs and develops the technology, and it then transfers the technology to NIDC.
- Technological cooperation or joint research and development (Joint R & D): in this method, designing and development are jointly carried out by NIDC and a company or research center outside the company. Although it is a common task, the research part of the project is often carried out outside the company, and its engineering part is performed by the development unit within NIDC.
- Innovation network: this method is actually a combination of two methods of contractual research and development and joint research and development. In this method, different companies and research centers, based on their expertise and research and engineering records, become in charge of the development projects needed by NIDC. NIDC will be responsible for coordinating and managing the network.

The following table makes it possible to compare the features of the different methods.

Table 6
The effect of identified factors on selected methods.

Need special resources and expertise within the company	Costs	Risk	Development time	Modification capability	Mastery of technology ownership	Control over results	Control over activities	Learning potential	Range of acquirable technologies	Increase of technological capability at national level	
Very High	High	Very High	Very Long	Very High	Very High	Very High	Very High	Very High	Very Low	Low	Internal research and development
Very Low	Medium	Low	Long	Low	High	High	Low	Low	Medium	Medium	Purchase or transfer of technology

Medium	Medium	High	Long	High	High	High	High	High	Low	Medium	Joint R & D
Low	Medium	Medium	Long	Medium	High	High	High	High	Very High	High	Innovation network

According to the characteristics of industry, the following items are considered for providing a suitable method of logging technology acquisition:

- NIDC is faced with the shortcomings of some equipment, and it urgently needs engineering operation unit (employers) to modern logging systems. Due to technical and strategic reasons cited in the study, there is a great need for the internal development of logging technology in Iran, in some branches of technology.
- Logging industry is the key and strategic technology to acquire petro-physical information and to identify data of oil and gas reservoirs, and the mastery over the technology in the long term leads to more preservation of oil and gas reservoirs information and the prevention of foreign companies' access to such information.
- NIDC is an engineering services company, and it is not advisable to spend a lot of money and energy to set up an R & D department in its internal structure. Moreover, considering the scope and the diversity of logging technologies, it is not possible to depend on a limited number of domestic suppliers. Therefore, it is better to have a network of companies and research centers with different kinds of expertise and experience in charge of developing the technologies required for logging industry. Local companies, if necessary or in case of economic or technical justification, can try to recognize and communicate with foreign technological companies. This also lets the discussed innovation network boundaries go beyond the technical and scientific limitations within the country.

In order to apply management, it is suggested to consider the following roles in the network:

- Network manager: NIDC is responsible for the management of the network and its related activities. Necessary governing strategies for applying management should be identified and implemented by the legal department of NIDC. These mechanisms could include strategies such as the followings:
    - Legal ownership of the technical knowledge produced in the innovation network;
    - Creating legal partnerships and establishing joint enterprises with innovation network members (companies, research centers, individuals etc.);
    - Clarifying the governing role of NIDC in consortium agreements among the members of innovation network;
- Network pole: it is the consulting and professional arm of the NIDC and is responsible for the coordination and supervision of innovation network activities on behalf of the company. Network pole should be a scientific/research center, preferably a valid university, and familiar with the technological issues of logging industry.
- Network members: the members of the network consist of powerful companies and research centers to develop logging technologies throughout the country. Each one of the members should at least own one of the following capabilities:
    - Futuristic monitor and the identification of products and technologies associated with the logging and feasibility industries and offering programs to develop technical knowledge;
    - Designing and developing technology to the extent of the first functional samples and according to the macro roadmap of logging technologies development;

- Communicating with prestigious research centers and foreign innovative companies to purchase products or to acquire technical knowledge;
- Integrating, scaling-up, mass-producing, and commercializing the developed technologies;

5. Conclusions

The aim of this study was to introduce a suitable method of acquiring well logging technology by the assistance of well logging industry experts through interviews and the application of theme analysis. According to the analyses, the managed innovation network is the optimal method for the acquisition and development of logging industry technologies within the country. Given the dynamicity of this technology inside the country, this network requires support, coordination, and guidance by NIDC to improve its objectives, effectiveness, and efficiency. The results indicate that NIDC has to use monitoring and coordination capabilities of valid scientific/research centers which are familiar with logging industry in order to manage innovation network with respect to specialized development of internal logging technology. Therefore, it is required to establish science centers throughout the country to scientifically and technically manage these centers under the supervision of NIDC. The purposefulness, effectiveness, and efficiency of the innovation network, which is developing logging industry technologies, fully depend on its management by NIDC.

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Nomenclature

NIDC	: National Iranian Drilling Company

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