Designing a Specific Model for Technology Transfer in Oil, Gas, and Petrochemical Sectors

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ABSTRACT

Latecomer players in oil, gas, and petrochemical industries should be technology holder in order to be competitive, and, in this context, catching up is mandatory for technological development. In this work, we have attempted to develop a process model for technology transfer in oil, gas, and petrochemical industries, which includes three stages of "decision making, technology transfer, and knowledge acquisition. The model is derived from the literature survey and developed based on the experiences while necessary elements are added to resolve the problems. So as to validate the model, demercaptanization distillate (DMD) technology transfer at Research Institute of Petroleum Industry (RIPI) was evaluated as a case study.

1- Introduction

Technology is viewed as a key for economic development. One opportunity for the technological development in industrializing countries is catching up (Khayyat & Lee, 2015). Technology transfer can facilitate this technological development process (Damijan & Knell, 2005).

The process through which a technological change occurs over time is substitution and diffusion. This process follows an s-shaped curve (Khayyat & Lee, 2015), and the s-shaped curve allows a late-starter to catch up. After the midpoint, the rate of technological change drops for a leader in that technology, while a follower, which is lower on the curve, has a higher change rate and consequently catches up. International technology transfer can be viewed as a strategy to aid the catch-up process; nevertheless, the acquisition of foreign technology by less developed countries has remained problematic. Putranto et al. (2003) describe an Indonesian experience with catching-up in the rolling stock industry; a process that took approximately 20 years. Keller (1996) observes that an outward-orientation of developing countries (for example through technology transfer) does not in general lead to a quick catch-up. He argues that this is because, although technology can be transferred (blueprints etc.), human capital has to be developed as well. If the rate of human capital formation is not increased with technology transfer, then the technological formation cannot be sustained (Keller, 1996, p. 203). Lee and Lim (2001, p. 459) made a similar observation stating that catching-up in technological capabilities is a function of the existing knowledge base, and Yin (1992, p. 24) found that recipients with adequate technological capability are in a better position to exploit economic and technological benefits from international technology transfer projects (Damijan & Knell, 2005; Steenhuis, de Bruijn, & Heerkens, 2007).

In order to catch up through technology transfer, it should be integrated and included the targeted chain of measures. Technology transfer is an important step in the development of every industry latecomer, including

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oil, gas, and petrochemical industries (Sahu, 2017; Back, Kovaleski & Junior, 2013). At present, the lack of a clear, comprehensive, and well documented manual for the transfer of high technologies in oil, gas, and petrochemical industries has led to serious challenges for the catch-up of latecomer players. Hence, in this study, by the analysis and the pathology of the non-modal and topical processes, a detailed process was developed to clarify the stages of technology transfer management (Gilsing et al., 2011).

2- A review of the literature on technology transfer

In general, technology transfer takes place in three ways: the transfer from the inside to the outside, the transfer from the inside to the inside, and the transfer from the outside to the inside. In this paper, the latter type, i.e. the transfer from the outside to the inside is considered.

On the other hand, technology transfer can happen on the basis of technology push or market pull. In the oil industry and in operational sectors, all license purchases come from the product market pull, and a very small percentage—less than 10% in number and less than 2% in monetary value—in research units is based on technology push. Transfer is carried out on a lab scale, bench scale, pilot plants, and basic design levels, which involves the technology transfer on various scales and the development of this knowledge to be utilized on an industrial scale. Furthermore, in the operational sectors that have the main share, technology transfer can be divided into upstream and downstream sections. In the onshore and offshore oil and gas upstream field, exploration areas (seismic exploration, exploration wells, and logging and data interpretation), extraction and development (well drilling, well completion, and production), and enhanced oil recovery (EOR) are parts of the technology transfer of National Iranian Oil Company (NIOC). In the downstream section, the commissioning section (liquefied natural gas (LNG) unit, mini-LNG unit, gas sweetening unit, gas refinery, gas to liquids (GTL) unit, and gas condensate refinery) and transportation (pipelines, LNG tanks, and CNG tanks) are part of the National Iranian Gas Company (NIGC) technology transfer. Moreover, in the downstream sector, the commissioning section (condensate refinery, heavy oil refinery, GTL unit) and the transportation of refined products are part of the National Iranian Oil Refining and Distribution Company (NIORDC) technology transfer. In the downstream section, the commissioning section (petrochemical raw material units and specialty petrochemical units) is part of the National Petrochemical Company (NPC) technology transfer.

Technology transfer is a complex and difficult process; purchasing and transferring technology without studying not only will be ineffective, but also can lead to the weakening of national technology in addition to wasting capital and time. The transfer should be seen as a process by which imported technology can be acquired not only for the production of the product, but also for the creation of new technology.

Technology transfer takes place in two ways: vertical and horizontal transfer; in the vertical transfer or transfer of research and development (R&D), technical information and research findings are transferred at the development and engineering design stage, and they then enter the production process through the technology commercialization (Omar, Takim, & Nawawi, 2011).

On the other hand, in a horizontal transfer, technology is transferred from one country to another one while maintaining the same level of capability. In this case, a higher receiver's level of technology reduces the transfer cost and causes the technology to be absorbed more effectively. Some of the factors affecting the way of transfer are as follows:

- The motivation, purpose, criterion, and profit agreed upon by the applicant and the technology provider;
- The level of technology and capabilities of the applicant for its complete transfer;
- Seller strategy for technology sales;
- Information resources available and the applicant's bargaining power;
- Applicant's general and current technological policy;

Since the main goal of this work is to design a model for technology transfer in oil, gas, and petrochemical industries, the identification of transfer models is of great importance. In general, there are five models for technology transfer, each of which has a particular view of the transfer. Each of these models includes effective measures on choosing transfer methods and the nature of transfer methods.

One of the most important models is the model of Chiisa and Manzini. The purpose of this model is to help decision makers who look for the acquisition of a particular technology from the outside because it provides the most appropriate method for collaborative technology based on certain steps. The model has 14 criteria which include: the purpose of cooperation, the ability to define the content of cooperation, familiarity with the market and technology, the competitive advantage ratio, the technology life cycle, the level of risk, the ability to protect the technology, the stage of the innovation process, the necessary capital, the way in which the parties communicate, the country of technology source, the field of activity, and the power and size of the parent company. In general, the Chiisa model is the most comprehensive model for recognizing the appropriate transfer methods, and it performs this process in three basic steps:

Step 1: Determine the characteristics of different transfer methods in terms of integrity level, formalism, amount of impact on the company, time horizon, control amount, cost, time to create cooperation, and flexibility;

Step 2: Determine the status of effective criteria for selecting the transfer method;

Step 3: Match the first and second steps and finally select the appropriate transfer method (Fang et al., 2013)

Another model for transfer is the Ford model, which includes five criteria that a company can use to determine the method of acquiring a technology. These criteria include: the competitive effect of technology, technology life cycle, the need for technology ownership, the immediate availability of technology, and the relative ability of the firm in technology. Although this model has fewer criteria and transfer methods than the Chiisa model, it covers internal R & D and is the most complete model for transfer after the Chiisa model (Simyar & Osuji, 2015).

The Roberts & Barry technology transfer model can be used to determine the technology access strategy. In this case, the technology strategy is the same as technology acquisition methods. This is a matrix model which communicates between technology acquisition techniques and company familiarity with market and technology. Each of these two criteria, namely the technology and the market, has three conditions: the base; the new and the known; and the new and the unknown (PRODAN, 2007).

Gilbert has also devised a model for technology transfer; the Gilbert matrix model is a four-part model based on two criteria of the desire and ability to meet the demands of the technology source and the control over the technology source to use it in accordance with the desired requirements and conditions. Based on the combination of these two criteria presented in the model in question and the yes/no answers, four classes of technology acquisition can be defined, each of which consists of several methods of transfer. These four categories are cooperative systems, anti-competitive systems, inactive systems, and public systems (Gilbert, 1995).

Another technology transfer model is the Stuck model, which is based on two criteria of uncertainty of technology and organizational interactions between the transmitter and transceiver of technology. Based on this model, the uncertainty of technology depends on three factors, including the emergence of technology, its complexity, and its tacit knowledge. In addition, organizational interactions depend on three factors of communication, coordination, and collaboration. Each of the uncertainty measures of technology and organizational interactions has different statuses that range from bottom to top. The proper combination of these two criteria leads to the formation of four types of technology transfer processes, each of which provides effective approaches to transfer. These four processes include regular purchases, facilitated purchasing, joint activity, and joint development (Pietrobelli, 2018).

In addition to the transfer models, there are several methods for technology transfer, among which one may refer to technology transfer through foreign direct investment, joint investment, license contracts, turnkey contracts, import of capital goods and machinery, buy-back contracts, reverse engineering, technical assistance support services contracts, and the recruitment of scientific and technical personnel (Ghazinoori, 2005). However, today, there are some modern methods of technology transfer that can be mentioned: technical training of employees in the advanced industries; the establishment of subsidiary companies and the establishment of research centers in industrialized countries; the establishment of international scientific and technical circles and associations; the establishment of educational centers and high-level research within the country led by academics and advanced research institutes and universities; academic exchange through universities; cooperation of domestic industries with foreign industries; strategic cooperation; registration of inexpensive foreign patents in the country; the acquisition of foreign companies or the purchase of some of their shares; hiring foreign experts and scientists; and the creation of databases (Bandarian, 2005).

A general survey reveals that western countries and technology transferring have three types of technology:

Type I: proven and tested technology that is economically feasible and environmentally friendly.

Type II: Unproven and untested technology, whose production efficiency and product quality are either uncertain or of low quality.

Type III: The untested technologies, or so-called obsolete ones, which have been abandoned in some countries due to the low production efficiency, finished product price, high production costs, high energy consumption or environmental reasons.

In many cases, technology type I is not usually offered for sale, or its sale is restricted for developing countries. This will put the technology types II and III in the hands of developing countries, mainly for sale.

A successful technology transfer requires the recognition of industry goals, technology resources, how to invent and transfer technology, transfer methods, effective factors, and how to absorb and develop technology; each knowledge also needs its own specialty.

The purpose of technology absorption is that, at the end of the technology transfer contract, the company can access the technology of the equipment by copying parts and re-designing based on the deep analysis of the technology and the needs and requirements of the new technology. In this context, the receiver is obligated to study the details of imported technology, its compatibility with internal factors such as required human resource, information and know-how, equipment and machinery, management and organization as well as external factors such as economic, social, cultural, and political infrastructures in the country. The receiver is able to function so that the actualization of technology in the receiver domain is realized. The purpose of technological actualization is the localization of a specific technology in such a way that the receiver, after absorbing technology and obtaining the necessary readiness and designing abilities, will be able to adapt imported technology to the local conditions, change and adaptation of production processes, know-how information and organization management with the new conditions (Jain et al., 2003).

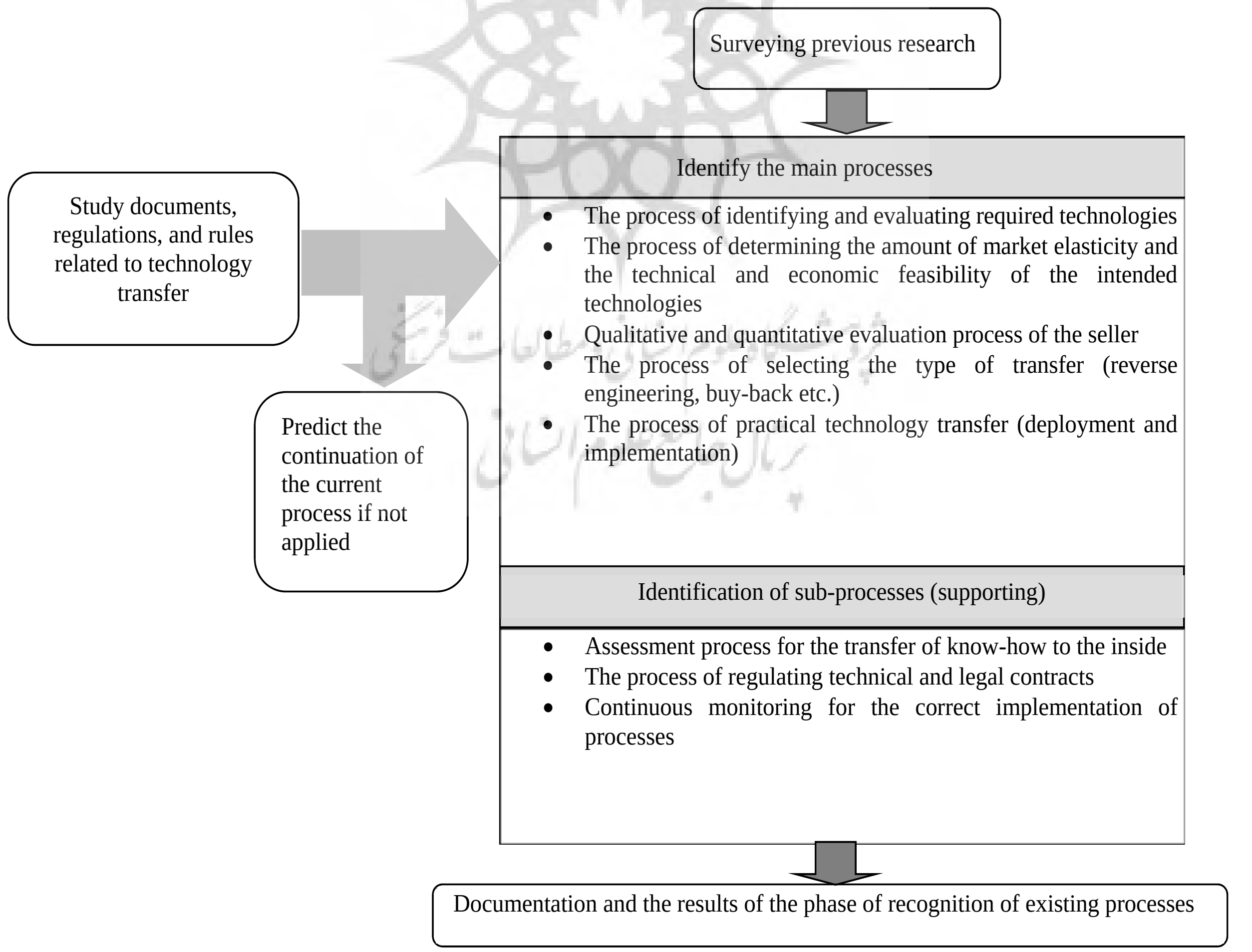

Figure 1: How to identify the existing processes for the recognition phase

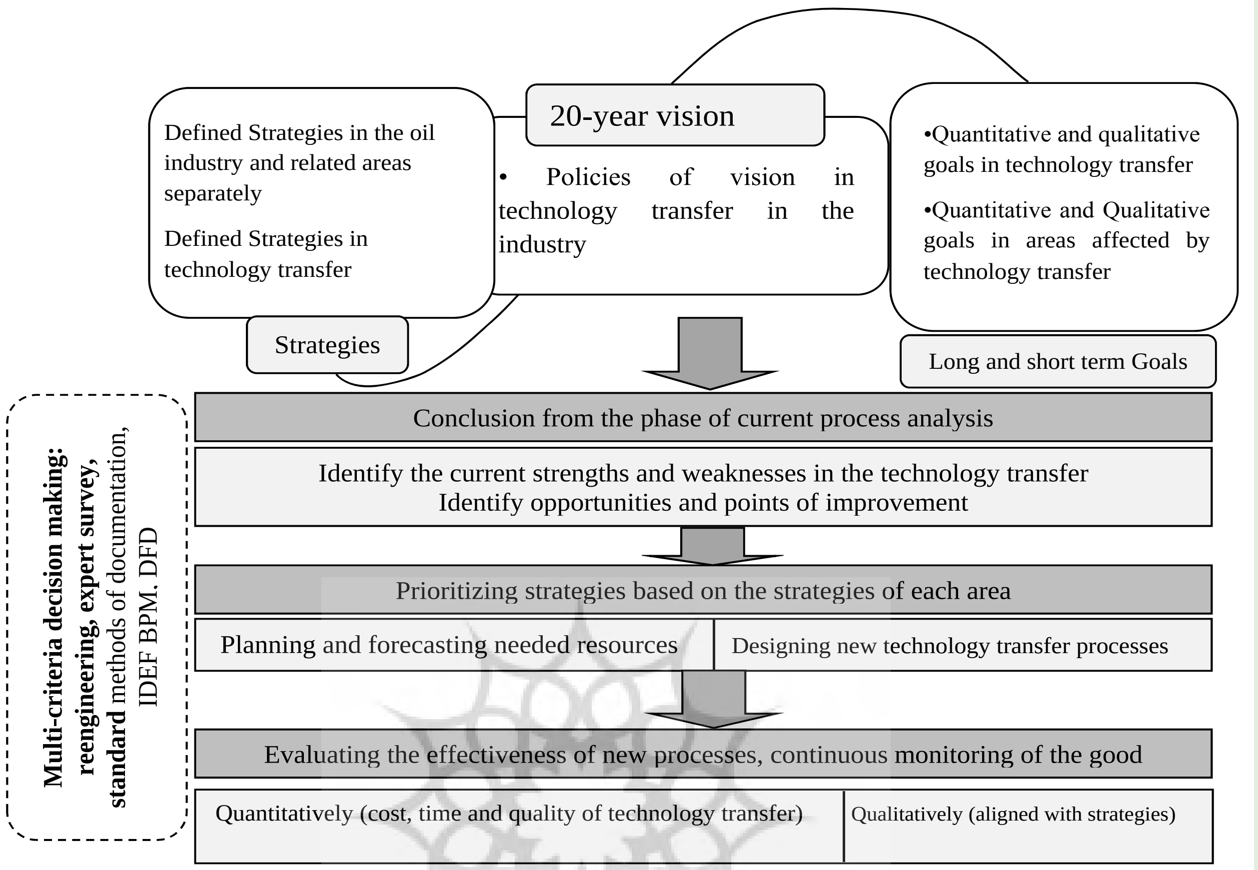

Figure 2: How to survey relation between strategies, vision, long- and short-term goals, and decision making

3- Methods of technology transfer in oil, gas, and petrochemical industries

At present, several methods are used to transfer technology in oil, gas and petrochemical industries, but, in order to design a specific model of technology transfer in the industry; the current methods should be reviewed. One of the most complete and effective ways of reviewing and improving business processes in each area, including the field of technology transfer is processes reengineering which has been developed with the aim to procure and establish new and desirable processes instead of current processes.

In general, three steps are needed to reengineer technology transfer in the oil industry:

Step 1: Understand the current situation;

Step 2: Analyze and classify the results;

Step 3: Establish a desirable system (Ghazinoori, 2005).

In the first step, the identification of the existing situation requires that the documents in the field of technology transfer be reviewed in oil, gas, and petrochemical industries, and the main processes and transfer support will be identified. The steps are shown in Figure 1.

It is also necessary to undertake the next steps, the analysis and classification of the results, as well as the establishment of a desirable system; it is also required to design new transfer processes after summarizing the results of the phase of recognition and planning and forecasting the required resources. This action is possible by taking into account the strategies set by the country oil industry, by considering the 20-year vision document, and by regarding the goals of this industry. The steps are listed in detail in Figure 2.

4- Methodology of research

To design a specific model for technology transfer in oil, gas, and petrochemical industries, it is necessary to first identify the main stages of transfer. For this purpose, a comprehensive study was carried out on the technology transfer models, and the stages of each model were extracted. Also, current methods of technology transfer in oil, gas, and petrochemical industry have been investigated with the aim of presenting the current status. The result of these studies was the extraction of indicators for the technology transfer in oil, gas, and petrochemical industries, and these indicators were taken into account by considering the technology transfer in this industry. Some of the most important considerations are the current strategies, the 20-year vision, and the goals and objectives of the industry. In the next stage, based on the experts' opinion, the indicators were screened, and the final indexes of the model were selected. At this stage, we tried to select indicators approved by field experts and consider various dimensions of the transfer process as much as possible. The steps for conducting the research are illustrated in Figure 3.

5- The proposed model for technology transfer process

The main objective of this study is to design a technology transfer model in oil, gas, and petrochemical upstream and downstream industries (Dhebar, 2016; Bhuiyan, 2011; Aarikka-Stenroos & Sandberg, 2012). Based on the studies carried out, the indicators in the proposed transfer model can be categorized in three main steps: 1. Decision making; 2. Technology transfer; and 3. Knowledge acquisition using a specific acquisition approach (knowledge acquisition in order to be a technology holder). These steps are shown in Figures 4-6, and the main activities are presented below each step.

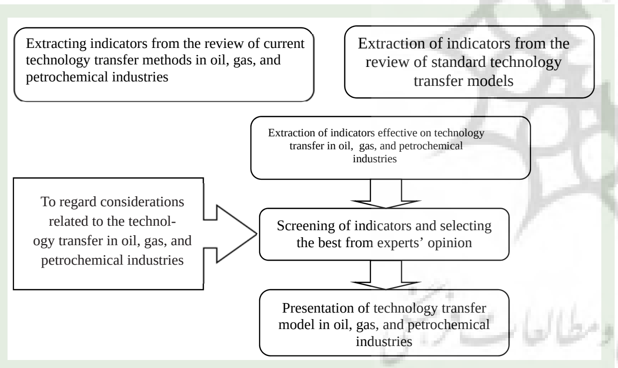

Figure 3: Research steps

Figure 4. Describing the decision-making process of the specific model of technology transfer in oil, gas, and petrochemical industries.

As shown in Figure 4, the first stage of the technology transfer model is decision-making. As mentioned above in the literature survey, technology transfer can be conducted through technology push or market pull. Regardless of whether technology transfer is performed through any of these methods, decision-making involves taking steps such as identifying and choosing technology, identifying seller, negotiation, selecting licensor, financing, and contracting technology transfer.

The second phase of the model involves technology transfer. Regardless of whether the transfer is carried out through knowledge management or patents and license, this step involves steps such as preparing a transfer plan, providing infrastructure, transferring know-how, acquiring skills, manufacturing or purchasing equipment, installing equipment, and testing and commissioning (Figure 5).

As seen in Figure 6, the final stage of the model also involves acquiring knowledge using the acquisition approach (to be technology holder). This

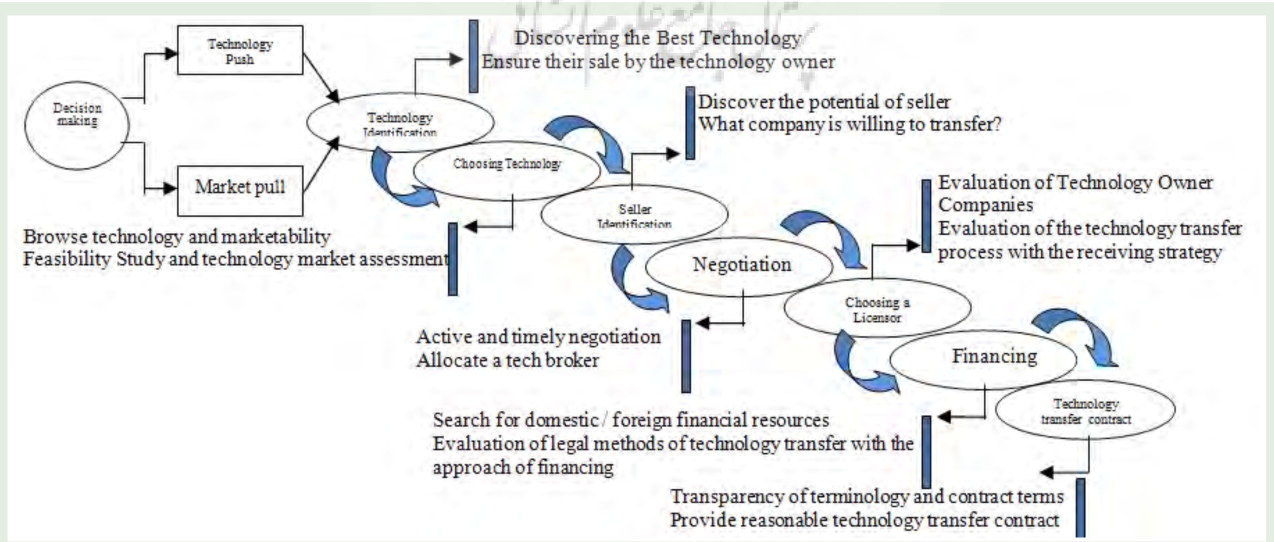

Figure 4: Describing the decision-making process of the specific model of technology transfer in oil, gas, and petrochemical industries

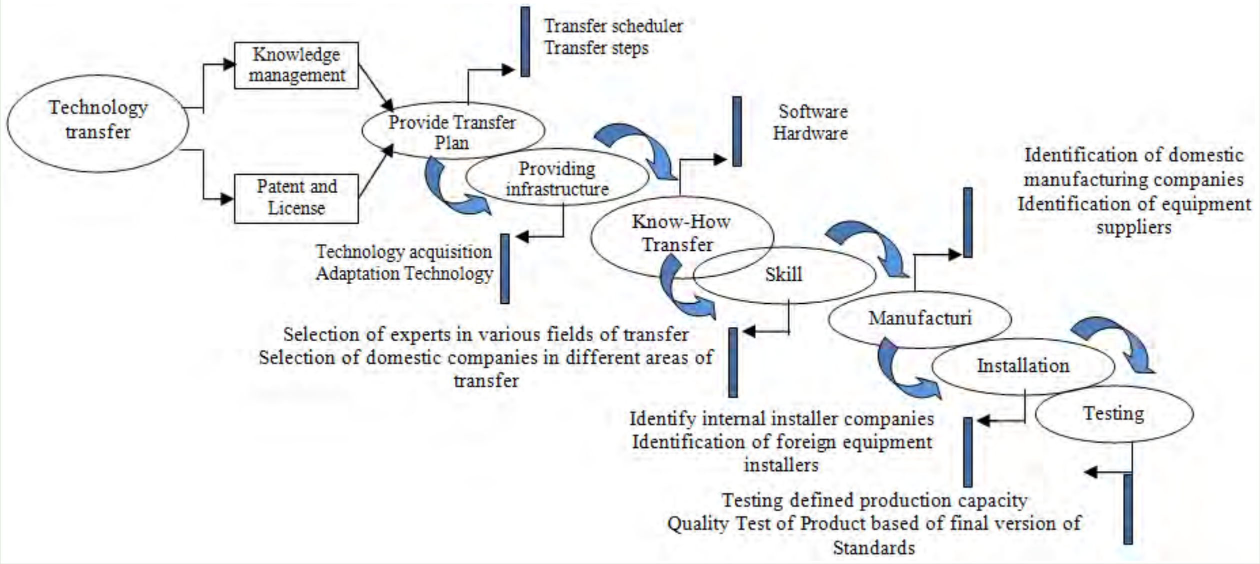

Figure 5: Describing the technology transfer phase of the specific model of technology transfer in oil, gas, and petrochemical industries

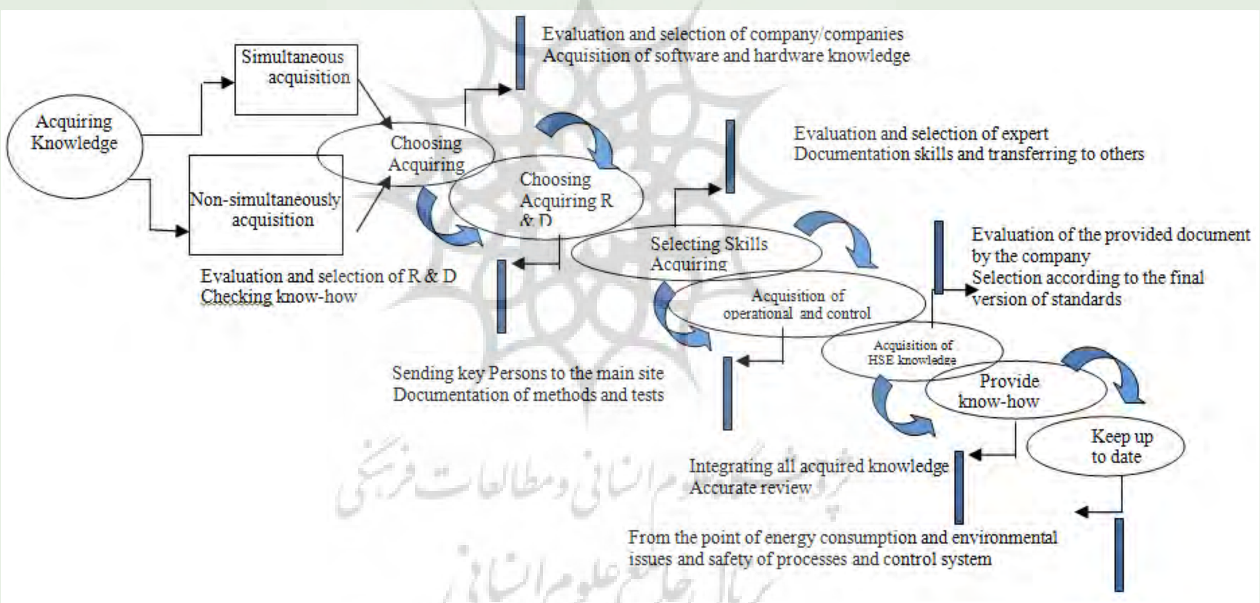

Figure 6: Describing the knowledge acquisition stage using the specific acquisition approach (knowledge acquisition in order to be technology holder) to

step, which can be conducted simultaneously or non-simultaneously, involves the steps of selecting the company and acquiring R&D; selecting the skills-gathering individuals; gaining operational knowledge and control; obtaining the knowledge of the health, safety, environment (HSE); preparing the know-how package; and keeping it up-to-date.

6- Case Study: DeMercaptanization Distillate (DMD) technology transfer

Using the demercaptanization distillate (DMD), mercaptans in intermediate distillation, crude, and condensate products can be eliminated. As a case study, DMD technology transfer has been used to run the model at Research Institute of Petroleum Industry (RIPI), and the weighing and results are tabulated in Table 1; the corresponding explanations are also presented in Table 2.

In order to compare different alternatives in the process of model implementation, the SWARA method as a one of the multi-attribute decision-making (MADM) techniques was used. The main feature of SWARA method is the possibility to estimate experts' or interest groups' opinion about the significance

Table 1- Results of the research model for

Main stage	Sub stage	General indicator	Final weight	Maximum score	Acceptance in instability condition	Acceptance in stability condition	Case study result (score of 100)	Finalized number	Acceptance	Acceptance status in stability condition
Decision making	Technology identification	Discovering the best technology	0.643	64	16	32	45	29	Ok	Not-ok
		Ensure their sale by the technology owner	0.357	36	9	18	25	9	Ok	Not-ok
	Choosing technology	Browse technology and marketability	0.655	66	16	33	31	20	Ok	Not-ok
		Feasibility study and technology market assessment	0.345	34	9	17	28	10	Ok	Not-ok
	Seller identification	Identification and evaluation of vendors	0.505	50	13	25	33	17	Ok	Not-ok
		Discover the potential of seller	0.198	20	5	10	28	6	Ok	Not-ok
		What company is willing to transfer?	0.297	30	7	15	53	16	Ok	Ok
	Negotiation	Selection of the negotiating team	0.266	27	7	13	59	16	Ok	Ok
		Selection of the negotiation strategy	0.479	48	12	24	70	34	Ok	Ok
		Selection of the scenario to give up or get points in the negotiation path	0.157	16	4	8	68	11	Ok	Ok
		Allocate a tech broker	0.098	10	2	5	75	7	Ok	Ok
	Choosing a licensor	Evaluation of technology ownership companies	0.630	63	16	31	80	50	Ok	Ok
		Evaluation of the technology transfer process with the receiving strategy	0.370	37	9	19	70	26	Ok	Ok
	Financing	Search for domestic financial resources	0.107	11	3	5	80	9	Ok	Ok
		Search for foreign financial resources	0.182	18	5	9	75	14	Ok	Ok
		Evaluation of legal methods of technology transfer with the approach of financing by investors	0.254	25	6	13	63	16	Ok	Ok
		Evaluation of the drafting of financing contracts of technology transfer by investors	0.457	46	11	23	58	27	Ok	Ok
	Technology transfer contract	Transparency of terminology and contract terms	0.264	26	7	13	40	11	Ok	Not-ok
		Transparency of terminology, contract terms and attachments	0.143	14	4	7	33	5	Ok	Not-ok
		Consideration of all stages of transfer and knowledge acquisition with the acquisition approach	0.079	8	2	4	35	3	Ok	Not-ok
		Provide reasonable technology transfer contract	0.514	51	13	26	48	25	Ok	Not-ok
Technology transfer	Provide transfer plan	Technology transfer schedule	0.132	13	3	7	75	10	Ok	Ok
		The timing of transfer steps	0.076	8	2	4	68	5	Ok	Ok
		Considering penalty for delay in each step	0.017	2	0	1	80	1	Ok	Ok
		Considering the rewards for completing each stage less than the dedicated time	0.012	1	0	1	75	1	Ok	Ok
		Extraction of technology transfer stages	0.453	45	11	23	68	31	Ok	Ok
		Preparing infrastructure for each stage	0.027	3	1	1	48	1	Ok	Not-ok
		Allocation of budget for each step	0.238	24	6	12	60	14	Ok	Ok
		Identification and evaluation the required expertise of each stage	0.045	4	1	2	65	3	Ok	Ok

Main stage	Sub stage	General indicator	Final weight	Maximum score	Acceptance in instability condition	Acceptance in stability condition	Case study result (score of 100)	Finalized number	Acceptance	Acceptance status in stability condition
Technology transfer	Providing infrastructur	Software technology acquisition	0.049	5	1	2	45	2	Ok	Not-ok
		Hardware technology acquisition	0.138	14	3	7	34	5	Ok	Not-ok
		Technology adaptation with input feed characteristics	0.484	48	12	24	70	34	Ok	Ok
		Technology adaptation with environmental requirements	0.248	25	6	12	28	7	Ok	Not-ok
		Technology adaptation with acquitted other technologies	0.081	8	2	4	36	3	Ok	Not-ok
	Know-how Transfer	Identification and evaluation of software used in the development of license / know-how	0.130	13	3	6	65	8	Ok	Ok
		Identification and evaluation of software used in the industrial plant	0.445	44	11	22	55	24	Ok	Ok
		Pass the course of software used in development of license / know-how by expert	0.076	8	2	4	31	2	Ok	Not-ok
		Pass the course of software used in the industrial plant by expert	0.234	23	6	12	33	8	Ok	Not-ok
		Identification and evaluation of maps and catalogs of equipment beside license / know-how personnel developer	0.009	1	0.2	0.4	55	0.5	Ok	Ok
		Identification and evaluation of equipment performance beside license / know-how personnel developer	0.012	1	0.3	0.6	60	0.7	Ok	Ok
		Identification and evaluation of equipment operation condition beside license / know-how personnel developer	0.046	5	1	2	55	3	Ok	Ok
		Investigation of equipment maintenance	0.029	3	1	1	44	1	Ok	Not-ok
		Pass the course of maintenance of industrial plant in one of the similar units during the overhaul	0.019	2	0.5	1	38	1	Ok	Not-ok
	Skill acquisition Manufacturing/purchasing equipment	Identification and evaluation of experts in (various fields of transfer (software / hardware	0.513	51	13	26	68	35	Ok	Ok
		Selection of experts in various fields (of transfer (software / hardware	0.270	27	7	14	59	16	Ok	Ok
		Identification and evaluation of domestic companies in various fields (of transfer (software / hardware	0.142	14	4	7	70	10	Ok	Ok
		Selection of domestic companies in vari-(ous fields of transfer (software / hardware	0.075	7	2	4	50	4	Ok	Ok
	Skill acquisition Installation of equipment	Identification and evaluation of required equipment and possibility of domestic manufacturing	0.472	47	12	24	60	28	Ok	Ok
		Identification and evaluation of domestic manufacturing companies	0.248	25	6	12	50	12	Ok	Ok
		Selection of domestic manufacturing companies	0.134	13	3	7	70	9	Ok	Ok
		Receiving certificate from licensor	0.075	7	2	4	65	5	Ok	Ok
		Identification and evaluation of equipment suppliers	0.044	4	1	2	49	2	Ok	Not-ok
		Selection of equipment suppliers	0.027	3	1	1	68	2	Ok	Ok

Main stage	Sub stage	General indicator	Final weight	Maximum score	Acceptance in instability condition	Acceptance in stability condition	Case study result (score of 100)	Finalized number	Acceptance	Acceptance status in stability condition
Technology transfer	Installation of equipment Skill acquisition Manufacturing/purchasing equipment	Identification and evaluation of required equipment and possibility of domestic manufacturing	0.472	47	12	24	60	28	Ok	Ok
		Identifica tion and evaluation of domestic manufacturing companies	0.248	25	6	12	50	12	Ok	Ok
		Selection of domestic manufacturing companies	0.134	13	3	7	70	9	Ok	Ok
		Receiving certificate from licensor	0.075	7	2	4	65	5	Ok	Ok
		Identification and evaluation of equipment suppliers	0.044	4	1	2	49	2	Ok	Not-ok
		Selection of equipment suppliers	0.027	3	1	1	68	2	Ok	Ok
	Installation of equipment	Identification and evaluation of domestic installer companies	0.483	48	12	24	35	17	Ok	Not-ok
		Getting a guarantee from domestic manufacturing companies	0.254	25	6	13	25	6	Ok	Not-ok
		Getting a warranty from domestic manufacturing companies	0.138	14	3	7	25	3	Ok	Not-ok
		Identification and evaluation of foreign installer companies	0.069	7	2	3	41	3	Ok	Not-ok
		Getting a guarantee from foreign manufacturing companies	0.036	4	1	2	53	2	Ok	Ok
		Getting a warranty from foreign manufacturing companies	0.020	2	0	1	60	1	Ok	Ok
	Testing and commissioning	Testing defined production capacity	0.500	50	12	25	45	22	Ok	Not-ok
		Quality test based on final version of standards	0.263	26	7	13	27	7	Ok	Not-ok
		Product quality testing with the latest standard	0.146	15	4	7	60	9	Ok	Ok
		Environmental standards monitoring for each product	0.091	9	2	5	35	3	Ok	Not-ok
	Choosing acquiring company	Identification and evaluation of acquiring companies	0.509	51	13	25	55	28	Ok	Ok
		Selection of acquiring companies	0.268	27	7	13	80	21	Ok	Ok
		Acquisition of software knowledge	0.078	8	2	4	70	5	Ok	Ok
		Acquisition of hardware knowledge	0.145	14	4	7	60	9	Ok	Ok
Acquiring knowledge	Choosing acquiring R&D	Identification and evaluation of R&D	0.512	51	13	26	75	38	Ok	Ok
		Selection of R&D	0.269	27	7	13	65	18	Ok	Ok
		Know-how evaluation	0.142	14	4	7	45	6	Ok	Not-ok
		Know-how confirmation	0.077	8	2	4	55	4	Ok	Ok

Main stage	Sub stage	General indicator	Final weight	Maximum score	Acceptance in instability condition	Acceptance in stability condition	Case study result (score of 100)	Finalized number	Acceptance	Acceptance status in stability condition
	Selecting skills acquiring persons	Identification, evaluation, and selection of experts	0.508	51	13	25	75	38	Ok	Ok
		Selection of expert	0.267	27	7	13	65	17	Ok	Ok
		Documenting skills and transferring to others	0.080	8	2	4	55	4	Ok	Ok
		Transferring skills to others	0.144	14	4	7	25	4	Ok	Not-ok
	Acquisition of operational and control knowledge	Sending key persons to the main site	0.174	17	4	9	70	12	Ok	Ok
		Provide a plan for personnel to document their observations	0.531	53	13	27	50	27	Ok	Ok
		Documentation of methods, tests and equipment maintenance	0.295	30	7	15	35	10	Ok	Not-ok
	Acquisition of HSE knowledge	Evaluation of the document provided by the company according to the final version of standards	0.103	10	3	5	65	7	Ok	Ok
		Review HSE guidelines at licensor plant	0.164	16	4	8	45	7	Ok	Not-ok
		Localization of HSE guidelines at industrial plant	0.461	46	12	23	55	25	Ok	Ok
		Review the iso's acquired by licensor	0.271	27	7	14	35	9	Ok	Not-ok
	Provide know-how package	Integrating all acquired knowledge	0.084	8	2	4	45	4	Ok	Not-ok
		Implementing knowledge management in the industrial unit	0.273	27	7	14	35	10	Ok	Not-ok
		Revise and update the acquired knowledge	0.491	49	12	25	25	12	Ok	Not-ok
		Registration of new technical and managerial experience at the industrial plant	0.152	15	4	8	26	4	Ok	Not-ok
	Keep up to date	Energy consumption at industrial plant	0.498	50	12	25	45	22	Ok	Not-ok
		Environmental requirements	0.269	27	7	13	50	13	Ok	Ok
		Process safety	0.145	15	4	7	35	5	Ok	Not-ok
		Industrial control systems	0.088	9	2	4	40	4	Ok	Not-ok

Table 2- Results of the research model for the transfer of DMD technology at RIPI

Main stage	Sub stage		Market pull	Technology push	Explanations
Decision making	Technology identification	Discovering the best technology	√		Identifying two processes similar to the DMD process, called the Sulfrex process and the Merox process
		Ensure their sale by the technology owner	√		Identification of Vniius Russia
	Choosing technology	Browse technology and marketability	√		Finally, by the judgment of the technical experts and authorities, the DMD process was selected
		Feasibility study and technology market assessment	√		The refineries demand DMD technology and its strategy for the oil and gas industry
	Seller identification	Discover the potential of seller	√		With the imposition of sanctions, western companies prevented technology transfer to Iran
		What company is willing to transfer?	√		Vniius's desire to transfer its technology and even produce its catalyst inside the country
	Negotiation	An active and timely negotiation	√		With the imposition of sanctions and market demands, the talks were conducted with the assistance of the presidential technology cooperation office, RIPI, and Vniius
		Allocate a tech broker	√		The office of presidential technology cooperation, which served as a technology monitoring center in this project
	Choosing a licensor	Evaluation of technology ownership companies	√		Evaluation of UOP, IFP, and Vniius
		Evaluation of the technology transfer process with the receiving strategy	√		Recipient strategy, basic and detail design by RIPI
	Financing	Search for domestic/ foreign financial resources	√		RIPI financing
		Evaluation of legal methods of technology transfer with the approach of financing	√		By the vice president of technology and international relations, with the assurance of the correctness of the technical evaluation
	Technology transfer contract	Transparency of terminology and contract terms	√		By the engineering research division, on how to contract and relevant international issues and ongoing bargaining on pricing and costs and finalizing the contract
		Provide reasonable technology transfer contract	√		Signing a joint cooperation agreement by the legal and international unit with the possibility of licensing to the domestic companies jointly
Technology transfer	Provide transfer plan	Transfer scheduler	√	√	At the same time as technology transfer, basic design and pilot manufacturing
		Transfer steps	√	√	Signing the contract, sending the feed data, basic and detailed design, pilot manufacturing, and industrialization
	Providing infrastructure	Technology acquisition	√	√	Transferring technology content (concept) along with all written and non-written information of technology by Vniius
		Adaptation technology	√	√	The design of industrial units DMD for the oil industry and the development of similar processes
	Know-how transfer	Software	√	√	The basic and detailed design of the process is fully realized by the experts of RIPI as well as modeling and simulation of the extractor reactor
		Hardware	√	√	Manufacturing the necessary equipment and components as far as possible inside the country
	Skill acquisition	Selection of experts in various fields of transfer	√	√	So that RIPI alone can set up DMD units on an industrial scale
		Selection of domestic companies in different areas of transfer	√	√	Research division for development engineering
	Manufacturing/purchasing equipment	Identification of domestic manufacturing companies	√	√	Identification of domestic manufacturers of vessels, heat exchangers, etc.
		Identification of equipment suppliers	√	√	Identification of foreign suppliers for some pumps and instruments
	Installation of equipment	Identify internal installer companies	√	√	Identification of domestic installing companies due to the sameness of design and construction combination on pilot and industrial scale
		Identification of foreign equipment installers	√	√	Installation and commissioning of pilot with the help of domestic companies and Vniius
	Testing and commissioning	Testing defined production capacity	√	√	Capacity test by the RIPI
		Quality test based on final version of standards	√	√	Improvement and upgrading the quality of petroleum products and standards

Main stage	Sub stage		Market pull	Technology push	Explanations
Acquiring knowledge	Choosing acquiring company	Evaluation and selection of company/companies	√		RIPI
		Acquisition of software and hardware knowledge	√		Acquisition of knowledge of the basic and detailed design of the process is fully realized by the experts of the RIPI and the manufacture of the required equipment and components in inside of the country
	Choosing acquiring R&D	Evaluation and selection of R&D	√		Full understanding of the transfer process and technical design of the equipment by the development engineering research division
		Checking know-how	√		Development engineering research division
	Selecting skills acquiring persons	Evaluation and selection of expert	√		Legal and international unit, development engineering research division
		Documenting skills and transferring to others	√		Commissioning of DMD units at the industrial scale for Gasoline and NGL and LPG
	Acquisition of operational and control knowledge	Sending key persons to the main site	√		Visiting the refinery that works with Vniius license
		Documentation of methods and tests			Commissioning, testing with different feeds and accessing design information
	Acquisition of HSE knowledge	Evaluation of the document provided by the company according to the final version of standards	√		Evaluation of all document by the RIPI
		Integrating all acquired knowledge	√		Getting all the relevant capabilities with this technology by RIPI from the DMD licensor
		Accurate review	√		Accurate review after pilot construction
	Keep up to date	From the point of energy consumption and environmental issues and safety of processes and control system	√		Vniius is obligated to inform RIPI from latest improvement.

ratio of the attributes in the process of their weight determination. The experts were RIPI staff from technical and managerial section, and the respondents' viewpoints were mostly based on the incomplete experiences and personal analysis regarding the questions.

Important points and assumptions made by the experts in weighing the indicators were as follows:

• The maximum score that can be obtained for each indicator is from a factor of 100 in the weight of the indicator (weighed by the SWARA method).

• The terms of stability mean that factors such as political, cultural, economic etc. as well as internal factors influencing decision making have a relative and appropriate stability.

• The purpose of situation instability are situations where the items of the previous article has been unstable in such a way as to distort the decision-making, such as the international sanctions condition in the current days

• The acceptance limit in terms of stability for each indicator is 50% of the maximum achievable score.

• Acceptance in the conditions of instability for each indicator is 25% of the maximum acceptable score.

• The result of the case study is the actual observed value for each indicator, which is a number between 0 and 100.

• The finalized number obtained for each indicator is obtained from the result of the multiplication of the "result of the case study" column by the indicator weight (the weight obtained by the SWARAH method).

7- Conclusion

The technology gap led oil, gas, and petrochemical industry managers to move toward technology transfer. Therefore, the need for a comprehensive and integrated model for technology transfer is felt more than ever. As a result, in response to this need, the process model of technology transfer in oil, gas, and petrochemical industries was developed, including three stages: decision making, technology transfer, and knowledge acquisition with a specific acquisition approach (knowledge acquisition in order to be technology holder). Decision-making involves taking steps such as identifying and choosing technology, identifying seller, negotiation, selecting licensor, financing, and contracting technology transfer. Regardless of whether the transfer is carried out through knowledge management or patents and licenses, this step involves steps such as preparing a transfer plan, providing infrastructure, transferring know-how, acquiring skills, manufacturing or purchasing equipment, installing equipment, and testing and commissioning. The final stage of the knowledge acquisition model (acquisition in order to be a technology holder) in a simultaneous or non-simultaneous acquisition involves selecting the company and acquiring R&D, selecting the skills-gathering individuals, gaining operational knowledge and control, obtaining the knowledge of the HSE, preparing the know-how package, and keeping up-to-date. The case study of DMD technology presents us with three stages of decision making, technology transfer, and knowledge acquisition (acquisition in order to be a technology holder). With all of their sub-sets for the application of the model and under conditions of economic instability, all the indicators related to the case study are higher than acceptance limit, and, in terms of economic stability, observations and points associated with some are not acceptable; however, in the current conditions that confirm international sanctions and related issues of instability, all the stages of study are accepted.

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