Petroleum Business Review, Vol. 6, No. 4, pp. 85–102, October 2022

Identifying and Prioritizing Technology Commercialization Components in the Iranian Oil and Gas Industries

Saeed Baghdadi[a], Abbas Khamseh[b*], and Hesamedin Madani[c]

[a] *Ph.D. Candidate, Department of Technology Management, Faculty of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran, Email: saeed.baghdadi@srbiau.ac.ir*

[b] *Associate Professor, Department of Industrial Management, Karaj Branch, Islamic Azad University, Karaj, Iran, Email: abbas.khamseh@kiau.ac.ir*

[c] *Assistant Professor, Department of Technology Management, Faculty of Management and Economics Science and Research Branch, Islamic Azad University, Tehran, Iran, Email: hesamedin.madani@gmail.com*

ARTICLE INFO

Keywords:

Independent technology commercialization capabilities

Oil and gas industries

Technology

Technology commercialization

Received: 21 February 2022
Revised: 22 June 2022
Accepted: 26 April 2021

How To Cite:

Saeed Baghdadi, Abbas Khamseh, and Hesamedin Madani, (Identifying and Prioritizing Technology Commercialization Components in the Iranian Oil and Gas Industries); *Vol. 6, No. 4, pp. 84–101, October 2022*

DOI:10.22050/pbr.2022.330861.1254

ABSTRACT

Knowledge and technology can be used as a capability to gain business benefits in organizations. In this regard, in addition to the use of technology in the production of products, technology commercialization to transfer technology to other organizations is considered a practical approach to gain business benefits. Accordingly, this study aimed to identify and prioritize commercialization components in Iran's gas and oil industry to transfer technology to other industries and organizations since there are high potentials to commercialize and transfer technology in this industry. After reviewing the previous literature and interviewing experts using semi-structured questions and the snowball sampling method, 46 attributes were detected and classified as 10 main components. Then, the confirmatory factor analysis method in SMART PLS software confirmed the 44 attributes in 10 components. Shannon's entropy method and WASPAS method were used to weigh and prioritize the extracted components. As a result of this research, the three main priorities of importance in the components of commercialization were identified the "enterprise capabilities of technology transfer", "technological capabilities and resources", and "independent technology commercialization strategies in the oil and gas industry" respectively.

* Corresponding author

1. Introduction

Leading and innovative organizations commercialize their technological achievements to complete the technology management cycle and improve the position of technology in creating wealth and reinforcing competitiveness capabilities. Several definitions have been proposed for technology commercialization, most of which have referred to commercialization as using technology to produce successful economic products in the market. [2] However, some experts define commercialization as technology transfer.[3] In a general classification, commercialization methods are classified into two categories: technology implementation and technology sale.[4] According to the previous studies, technology commercialization is considered the application of technology in producing products with fair prices and in accordance with the market needs.[5]

However, the present study focused on the concept 'commercialization' as the transfer of technology to other industries, including relevant or irrelevant industries, and technology-independent commercialization, because commercialization in governance policies[6] is presented as disseminating and applying technological achievements in various industrial organizations. As the prerequisite of this definition, it is necessary to detect the commercialization components and their main indicators. However, some industries in Iran have significant capabilities due to their long history in acquiring and implementing technology, which may not have been used in creating wealth and gaining economic benefits.

In Iran's oil and gas industry, despite passing above a decade of developing strategic documents on the commercialization and dissemination of technological achievements, huge international investments in technology development over recent decades, and the cooperation between Iranian companies and international partners, the acquisition of economic benefits from independent technology commercialization (technology sales and commercialization among companies) has been disregarded. Accordingly, the wealth created by companies from technology transfer is negligible compared to their products and services in sales.

According to a review of research on the oil industry and technology models[7], and interviews with chief managers, the concept 'technology commercialization based on the assignment of research achievements to organization developers was used as such companies can ultimately gain common benefits. In other words, in the aforementioned structure, commercialization as the transfer of technology to other firms to create wealth is not a priority. There was no goal in the strategic macro-documents to gain economic benefits from transferring or selling technological achievements and capabilities. On the other hand, due to the high cost of research and technology development in the oil industry, there should be new attitudes towards revenue generation from technology transfer so that technology development can be partly funded in this way.

Moreover, the current situation can be the result of insufficient knowledge and understanding of the required capabilities in enterprises to commercialize the technology in the oil and gas industry. Accordingly, the present study sought to answer two main questions: "What are independent technology commercialization components?" and "How are independent technology commercialization components prioritized? This study aimed to detect and prioritize independent technology commercialization components in the oil and gas industry so that chief managers can benefit from the findings to make strategic decisions about commercialization, especially in the development of technological capabilities according to the detected priorities and finally about the successful transfer of technology to other industries and organizations.

It is worth noting that the apparent aspect of contributions in this research is its focus on identifying commercialization components based on the technology exchange, gaining economic benefits, and creating wealth from those benefits; however, most similar studies have addressed commercialization in the form of developing new products by using technology, while in this study the concept of independent technology commercialization with the aim of gaining benefits from the sale and transfer of technology in the oil and gas

[2] Goldsmith, 2003
[3] Thanh Huyen, 2009; Khalil, 2004
[4] Dhewanto, Vital& Sohal, 2009
[5] Thanh Huyen, 2009

[6] Document of strategic transformation of science and technology, macro goals, and science and technology system
[7] The new structure of oil industry research and technology

industry has been emphasized. Some aspects of the novelty in this research are presented as shown below.

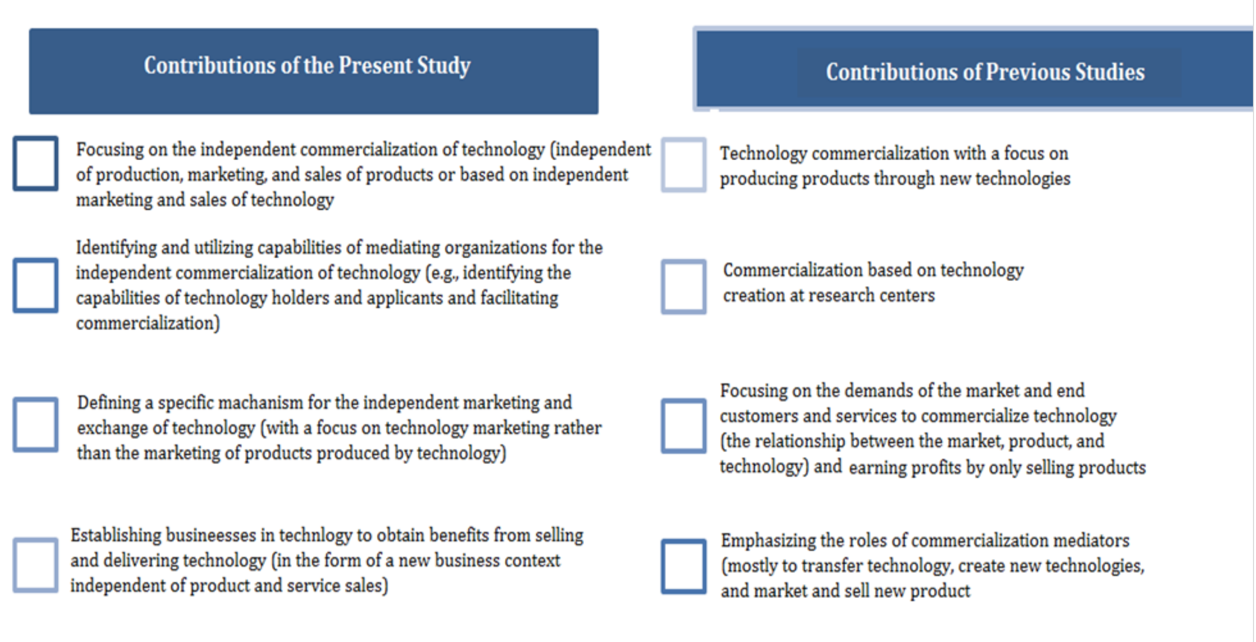

Figure 1: Comparison of the present study to previous studies

2. Theoretical foundations and literature review

After reviewing definitions and theoretical foundations, components extracted from previous studies on commercialization are discussed in this section. According to the common view based on Goldsmith's definition, commercialization, is a process of turning an idea into a product and selling it in markets (Goldsmith, 2003). In this view, commercialization is defined as the development of a business by applying the idea (product) and accepting it in the market and is equivalent to the transformation of technology into economical products. In another view, commercialization is equivalent to transferring and implementation of technology in different industries to produce and supply products and services. This definition focuses on the market and technology customers' needs[8]. In this regard, Markham[9] (2004) reported a clear relationship among technology, product, and market and stated that each technology could be used in different markets to produce products with multiple applications.

In another definition, commercialization is the creation and production of technology in research institutions during the research and development processes.[10] Accordingly, assigning the research achievements to others is considered as the commercialization process. Besides these views, Tariq Khalil considered marketing and transferring technology to other organizations to produce similar or different products as technology commercialization methods. In this view, commercialization is defined as the sale and exchange of technology (as capital goods) in relevant and irrelevant industries. In this regard, commercialization can be defined in implementing technology in the production and sale of products and in technology marketing and its direct sales.

According to the above definitions, several perspectives have dealt with technology commercialization, and their common point is the acquisition of economic benefits and revenue generated by technological capabilities with a focus on the market and customer needs. In the present study, commercialization is defined as the acquisition of economic benefits from technology transfer, which is defined as the concept of 'Independent Technology

[8] Thanh Huyen, 2009
[9] Markham,2004
[10] Benjamin, 2006

Commercialization.' Moreover, the present study's approach to commercialization is closer to Tariq Khalil's definition of technology commercialization.

According to a review of studies, the main variables of technology commercialization have been discussed from different perspectives. The review of the literature revealed that the commercialization components could be categorized into internal and external factors. Furthermore, some of the components associated with intra-organizational factors are technological capabilities, and some other factors are considered supporting ones.

In addition to the supporting components, some factors are considered specialized capabilities necessary for an expert in the field of technology commercialization. These factors have been addressed in several studies. In this regard, "the technology value proposition" is an influential factor in technology commercialization based on the findings of some studies (e.g., Malekzadeh, 2015; Goodarzi, 2012; Badegeshin,[11] 2019; Johnson [12] , 2009). "Recognizing technology market opportunities" has also been cited as another important factor in the Asia-Pacific commercialization handbook (2018) and Jae-Woong Mina, YoungJun Kimb, Nicholas S. Vonortas (2020). Moreover, Malekzadeh (2015) and Kim [13] (2019) believed that understanding "customer needs" is a critical factor in the success of commercialization.

Furthermore, Goodarzi (2012), Zahedi and Mir Ghafouri (2017), Badegeshin (2019), Kim (2019), and Forouzandeh and Qadian (2015) examined the impact of "inherent capabilities of technology in creating innovation on commercialization". In addition to the above factors, "understanding the life cycle of technology" was discussed in Malekzadeh (2015) and Khodadad Hosseini, Sohrabi (2009), Dinmohammadi, M. Shafiee (2017) and Jae-Woong Mina , YoungJun Kimb , Nicholas S. Vonortas (2020). Meanwhile, "recognizing the industry's technological challenges in commercialization" was proposed as another effective factor by Malekzadeh (2015).

Another intra-organizational factor is "product development capability", which has been emphasized as an influential factor in the success of the commercialization process (Goodarzi, 2012; Badegeshin, 2019; Johnson & Lieber, 2009). "Negotiability and capability to get under contract" is another intra-organizational component introduced by Ahmad Mousaei (2018), Khodadad Hosseini and Sohrabi (2009) and also in the Asia-Pacific Commercialization Handbook (2018). "Focusing on the multiple applications of technology" in the commercialization process is also highly important, as Park (2019) noted.

To other intra-organizational factors, these two components, namely "understanding the risk of commercialization" and "external partnerships in commercialization", are presented by Badegeshin (2019). On the other hand, the importance of the "technology business model" in the success of commercialization is discussed by Park (2019). Moreover, "recognizing the types of commercialization beneficiaries and understanding their expectations" were proposed by Michael (2010). Finally, Bin (2012) believed that technological learning capacity was effective in the success of the commercialization process.

In addition to the above factors, the extra-organizational factors effective in commercialization success have also been addressed. In this regard, Zahedi and Mir Ghafouri (2017), Johnson (2009), Dinmohammadi, M. Shafiee (2017) and Lybecker (2009) noted that "cultural and social contexts" play a critical role in technology commercialization. Safarlou (2013) also introduced "international politics and diplomacy in technology" as influential in technology commercialization. "The effectiveness of government support" and "the rules and regulations of government institutions" has also been raised as another factor by Bin (2012). "Maturity level of technology holder and technology receiver" is introduced as another external factor in a paper published by Mohammad Forouzandeh, Seyed Mehdi Qadian (2015). Finally, Hassan Safarlou, Mohsen Safarlou (2013) and Seyed Hamid Khodadad Hosseini, Ruhollah Sohrabi (2009), Dinmohammadi, M. Shafiee (2017) and Ravi, Manthan D, Janodia (2021) consider "intellectual property rights (IP) in commercialization" as an effective factor in technology commercialization.

In some studies, in addition to the introduced components, the role of technology transfer intermediaries in the success of the commercialization process has been discussed. The role of external

[11] Saheed A. G. Badegeshin
[12] Daniel K.N. Johnson, Kristina M. Lybecker
[13] Minseo Kim, Hyesu Park

intermediaries in providing "technology evaluation and consulting services" was presented by Hooshmandinia and Najafizadeh (2017), Sadeghi (2015), Ying (2012), and Reamer (2008). Moreover, the "intermediation services" by intermediaries were proposed by Howells (2006), and the valuation of technology using technological intermediaries was discussed in Samadi and Kolahdoozan's(2006) study. Finally, Sari (2017), Jae-Woong Mina, YoungJun Kimb, Nicholas S. Vonortas (2020) and Clayton (2018) discussed "providing resources, facilities, and commercialization infrastructure using technology intermediaries".

Zemlickiene (2020) studied the prioritization of the dimensions affecting technology commercialization. He introduced "that value created for the customer", "technology capabilities", "economic status and revenue generation", "workforce competency", "policies, competitive environment", and Legal rules as the most critical factors in the technology commercialization, focusing on ICT technologies. Further, in another study conducted by Bandarian (2012), different factors in the commercialization of new technology were evaluated. According to the findings of this study, technical, economic, and market dimensions received the highest score, respectively.

3. Research methodology

This research aims to identify and prioritize the independent technology commercialization components in the oil and gas industry. Thus, policymakers and managers in the oil and gas industry would benefit from its findings. The present research was applied in terms of objective and a descriptive survey in terms of methodology since the required data were collected using interviews with experts and questionnaires. In the present study, the library method was first used to collect data, review previous literature, and analyze the content of that literature. Then, extra components and indicators were identified using semi-structured interviews with industry experts. The statistical population of this phase encompassed the chief managers of the three leading companies affiliated with the Ministry of Oil, including the National Iranian Gas Company (NIGC), the National Iranian Oil Company (NIOC), and the National Iranian Oil Refining and Distribution Company (NIORDC), who were policymakers and experts in the oil and gas industry and whose expertise in research and technology was more concerned. Due to the limited number of experts in the field of technology commercialization in the oil and gas industry, sampling for interviews was conducted using the snowball sampling method, and eleven interviews were conducted to reach theoretical saturation. After the interview, a total of 46 attributes was categorized under ten main factors. Then, to confirm the obtained attributes, the confirmatory factor analysis and structural equations were calculated in SMART PLS software. Finally, two attributes were removed, and 44 attributes were approved. This software was used because of the following Advantages: insensitivity to small sample size, insensitivity to abnormal data, the use of hybrid measurement models, real ability to support moderating variables, ability to implement a researcher-made model, and the ability to use highly sophisticated models. To perform structural equations, a questionnaire was developed and submitted to 52 managers and senior experts engaging in research and technology in the oil and gas industry, of whom 52%, 34%, and 14% had bachelor's, master's, and Ph.D. degrees, respectively.

Moreover, in this study, the validation of the collected data was assessed based on reliability tests, including Cronbach's alpha, composite reliability (CR), and communality reliability. Furthermore, the study's validity was determined using the convergent validity test, divergent validity test, and measurement model quality test. Meanwhile, in the analysis of the structural model (internal model) and its evaluation, the standard equation of R2, Q2, and the goodness of fit (GOF) of the general model was performed with SMART PLS software. Finally, to prioritize the identified components, Shannon's entropy weighting method and the Weighted Aggregated Sum Product Assessment method (WASPAS) were calculated with MATLAB software. For this purpose, the prioritization questionnaire was completed by 11 industry experts.

4. Findings

In this study, after reviewing the literature, the concerned indicators and preliminary components were extracted, and then, based on semi-structured interviews with 11 industry experts, the final components and indicators were customized for the oil and gas industry. Finally, 46 indicators were determined under 10 main components, as presented in Figure 2.

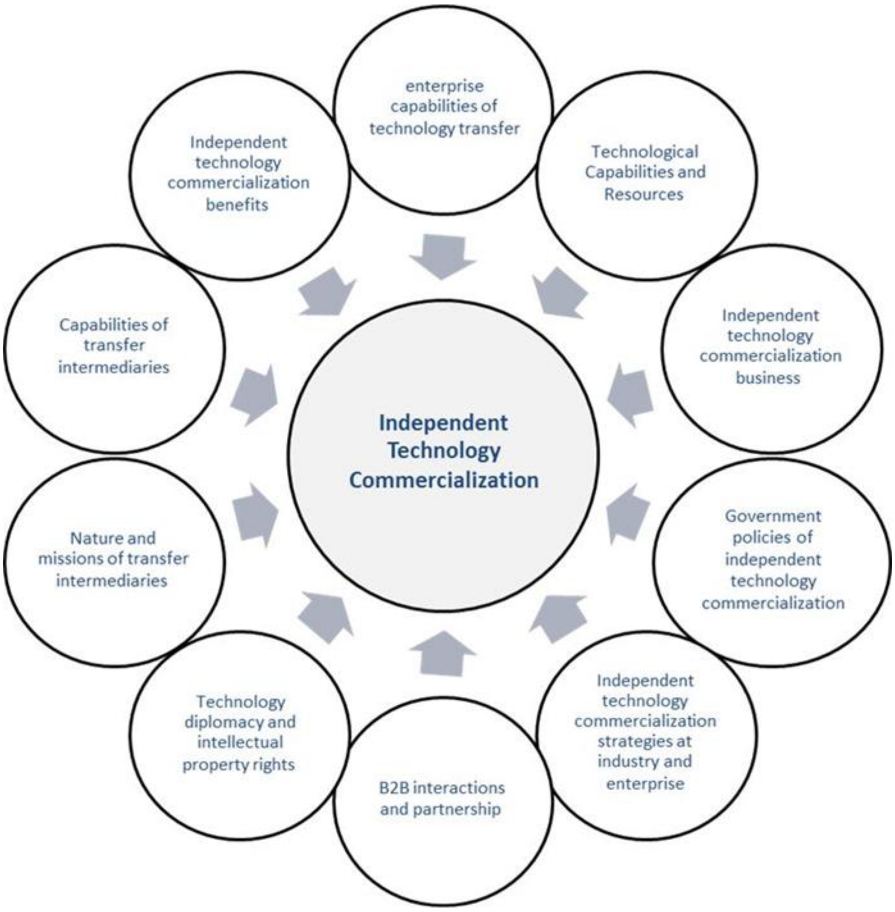

Figure 2: Key components for independent technology commercialization (research model)

Then, based on the data collected from the questionnaire completed by 52 managers and experts in the oil and gas industry's research and technology sector, each component's factor loading was calculated with SMART PLS software. Factor loading of commercialization indicators is presented in table 1.

Table 1: Factor loading of commercialization indicators

Components	Indicators	Variables code	Factor Loading
Enterprise capabilities of technology transfer (TT)	Capability of identifying and analyzing market opportunities	TT3	0/919
	Capability of identifying the demands and expectations of technology applications	TT4	0/846
	Capability of analyzing the data of technology competitors	TT6	0/754
	Capability of technology documentation and knowledge transfer	TT5	0/922
	Capability of valuating technology and registering patents	TT2	0/880

Components	Indicators	Variables code	Factor Loading
	Capability of negotiating and signing contracts	TT8	0/735
	Capability of localizing and deploying technology	TT1	0/904
	Capability of supporting technology	TT7	0/865
Technological Capabilities and Resources(TC)	Capability of understanding technology lifecycle	TC3	0/807
	Hardware capabilities of technology	TC1	0/786
	Software capabilities of technology	TC2	0/794
	Individual capabilities and knowledge	TC4	0/798
	Organizational capabilities and knowledge	TC5	0/779
	Commercialization infrastructure and resources	TC6	0/747
Independent technology commercialization business (CB)	Planning a technology business	CB2	0/857
	Economic analysis of commercialization	CB1	0/950
	Risk management of technology commercialization	CB3	0/958
	Distinguishing technology business from products	CB4	0/779
Government policies of independent technology commercialization (GR)	General technology commercialization policy	GR2	0/896
	Developing a technology commercialization ecosystem	GR 1	0/708
	Commercialization regulations and rules	GR 4	0/926
	Granting financial facilities for commercialization	GR 3	0/789
Independent technology commercialization strategies at industry and enterprise (CS)	Analysis of strategic factors	CS4	0/929
	Planning commercialization strategies	CS1	0/924
	Implementation of commercialization strategies	CS3	0/961
	Developing participatory strategies	CS2	0/758
B2B interactions and partnership (CI)	Learning and sharing experiences	CI3	0/917
	Developing external interactions	CI1	0/950
	Balancing the maturity levels of	CI2	0/931

Components	Indicators	Variables code	Factor Loading
	commercialization parties (i.e., the giver and receiver)		
Technology diplomacy and intellectual property rights (IP)	Understanding the technological capabilities of countries	IP1	0/461
	Realizing political factors in international transfer	IP2	0/929
	Monitoring intellectual property rule enforcement	IP3	0/910
	Management of intellectual property disclosure risk	IP3	0/887
Nature and missions of transfer intermediaries (IM)	Segmentation of mediating institutions	IM1	0/514
	Suitability of mediator function for commercialization services	IM2	0/929
	Developing specialized industry mediators	IM3	0/937
Capabilities of transfer intermediaries (IC)	Capability of providing the infrastructure and resources	IC1	0/717
	Capability of understanding market demand and entrepreneurship	IC3	0/840
	Capability of arbitrage/ intermediation services	IC2	0/859
	Capability of protecting intellectual properties	IC5	0/835
	Capability of networking and developing national and international interactions	IC7	0/809
	Capability of providing technological information and knowledge	IC6	0/744
	Capability of transferring and acquiring technology	IC4	0/845
Benefits of Independent technology commercialization (CR)	Realization of commercialization outcomes	CR1	0/864
	Gaining economic commercialization benefits	CR2	0/899
	Developing communications with technology applicants	CR3	0/818

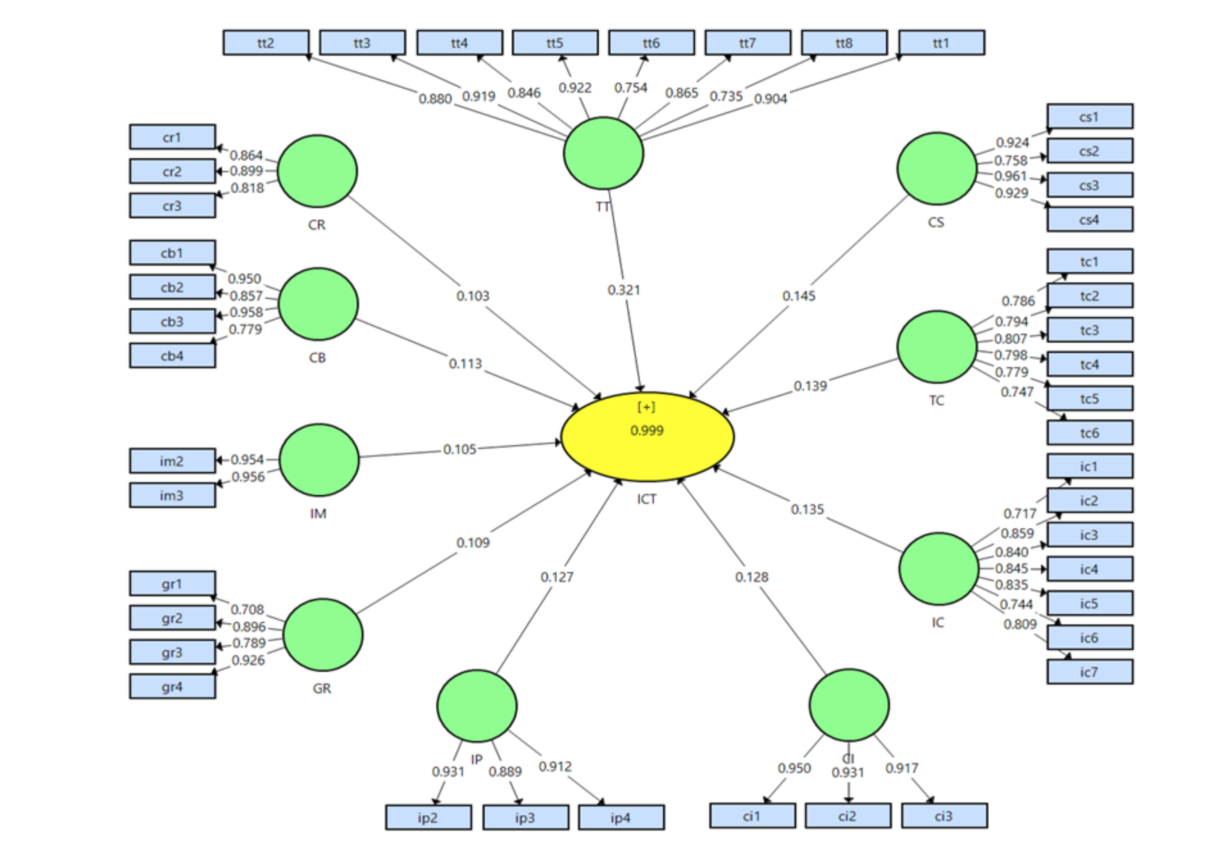

Figure 3: Corrective measurement model in the mode of estimating standard coefficients (loading Factor)

According to the SMART PLS software output, out of 46 indicators, 2 indicators (with code number IP1, IM1) had a factor loading of <0.7. To gain higher reliability and to maintain divergent validity in the model, the relevant questions were removed.

This study assessed data collection validation based on reliability tests, including Cronbach's alpha, composite reliability, and commonality reliability. According to Benitez et al. (2020), the value of the first two reliability tests must be >0.7, and the extracted average variance must be >0.5. As presented in Table 2, Cronbach's alpha for all factors is >0.7, confirming the model's reliability. Considering that the appropriate value for Cronbach's alpha and composite reliability is 0.7 and is 0.5 for communality reliability, based on the findings recorded in the above tables, the composite reliability, communality, and Cronbach's alpha coefficients obtained for the variables indicated acceptable internal consistency. Accordingly, the reliability of the research was confirmed.

Also, in the next test, the extracted average variance must be above or equal to 0.5 (Hair et al., 2018). In Table 2, all the extracted average variances are >0.5, so the convergence validity of the data is confirmed. On the other hand, to confirm the convergence validity, CR must exceed AVE (CR> AVE). As shown in Table 2, CR in all latent variables was > AVE (CR> AVE), and therefore the convergent validity condition was met.

Table 2: Model accreditation information

Component	Code	Cronbach's Alpha	Composite Reliability(CR)	Communality Reliability	Average Variance Extracted (AVE)	CR>AVE
Independent technology commercialization business	CB	0/911	0/937	0/790	0/790	OK

Component	Code	Cronbach's Alpha	Composite Reliability(CR)	Communality Reliability	Average Variance Extracted (AVE)	CR>AVE
B2B interactions and partnership	CI	0/926	0/943	0/870	0/870	OK
Benefits of Independent technology commercialization	CR	0/831	0/896	0/741	0/741	OK
Independent technology commercialization strategies at industry and enterprise	CS	0/917	0/942	0/804	0/804	OK
Government policies of independent technology commercialization	GR	0/854	0/901	0/696	0/696	OK
Capabilities of transfer intermediaries	IC	0/912	0/929	0/654	0/654	OK
Nature and missions of transfer intermediaries	IM	0/904	0/934	0/912	0/912	OK
Technology diplomacy and intellectual property rights	IP	0/897	0/936	0/829	0/829	OK
Technological Capabilities and Resources	TC	0/876	0/906	0/617	0/617	OK
Enterprise capabilities of technology transfer	TT	0/947	0/926	0/732	0/732	OK

On the other hand, the communality reliability index measures the model's ability to predict observable variables using their corresponding latent variable values. The positive values of the CV Com index indicate the appropriate quality of the dimensions. Hair (2018) shows that 0.15 and 0.35 are medium and strong figures for this weak index, respectively (CV Com).

Table 3: Coefficients of variation of common indicators

Component	Code	SSO	SSE	CV Com
Independent technology commercialization business	CB	208/000	82/436	0/604
B2B interactions and partnership	CI	156/000	56/612	0/637
Benefits of Independent technology commercialization	CR	156/000	87/341	0/440
Independent technology commercialization strategies at industry and enterprise	CS	208/000	80/963	0/611
Government policies of independent technology commercialization	GR	208/000	112/506	0/459
Capabilities of transfer intermediaries	IC	364/000	176/178	0/516
Nature and missions of transfer intermediaries	IM	104/000	46/525	0/553
Technology diplomacy and intellectual property rights	IP	156/000	66/441	0/574
Technological Capabilities and Resources	TC	312/000	173/115	0/445
Enterprise capabilities of technology transfer	TT	416/000	160/257	0/615

In Table 3, the high quality of commercialization indicators is determined in this research. To analyze the structural model, the coefficient of determination and predictive relationship test was used. The coefficient of determination always ranges between 0 and 1, and the coefficient values of 0.67, 0.33, and 0.19 in PLS route models are described as significant, moderate, and weak, respectively. The value of the coefficient of determination must be at least at a significant level (>0.67); otherwise, doubts are raised about the theoretical foundation of dimensions. The value of R2 indicates how much the independent variables together predict the behavior of the dependent variable (Hair, 2018). The obtained R2 value in this study is 0.999. The predictive correlation test (Q2) also measures the quality of the structural model, and the values of 0.02 (weak), 0.15 (medium), and 0.35 (strong) are the criteria for measuring this test (Henseler, 2011). In this study, the Q2 value is 0.353.

Finally, the GOF index was used to evaluate the quality of the structural model. This index examines whether the dimensions had the overall capability to predict and whether the dimensions tested in the present study successfully predicted endogenous latent variables. This value ranged from zero to one, and the closer the value is to one, the better the quality of the structural model. The values of 0.01, 0.25, and 0.36 were considered strong, medium, and weak, respectively (Hair et al., 2018). According to the GOF value in the present study (0.873), the suitability of the dimensions and the general structure of the independent technology commercialization are confirmed.

4.1. Prioritization of Independent Technology Commercialization Components

WASPAS method was used to prioritize the commercialization components, and Shannon‘s entropy method weighed each of the prioritized criteria. Prior to prioritization, based on a meeting with 11 oil and gas industry experts, independent technology commercialization dimensions were explained, the results of the hypotheses obtained from factor analysis were presented. Accordingly, the criteria for prioritizing the dimensions affecting commercialization were determined. Eight criteria were determined and classified under four main topics to prioritize the commercialization dimensions in this phase. The criteria were selected with the focus on technology business goals in the oil and gas industry and accompanied by the consensus of research and technology experts at the level of decision-making and policymaking.

Table 4: Segmentation of decision criteria to prioritize components

Achieving the business goals of enterprises in the industry		Reducing the oil industry's dependence on foreign companies		Transfer of technological capability of oil industry to other industries		Improving the technological capability of the oil industry	
Profitability	Efficiency	The ability to internalize technology	Currency savings	Technology transfer between industries	Technology diffusion at the national level	Technological capability of oil industry	Technological synergy within the industry

The eight selected criteria were weighed using the entropy method. This method is one of the valid methods in weighting decision criteria proposed by Shannon and River (1974). Because not all indicators are equally significant in multi-criteria decision-making and some indicators may be more or less significant than others, firstly, the weight of each criterion was determined using the abovementioned method according to the following steps.

1. First, the decision matrix is formed based on criteria and decision options. Then the decision matrix is normalized and the Pij is obtained by the following calculation.

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \qquad (1)$$

2. The entropy of each index (Ej) was then calculated as follows, and the K number as a constant value, puts Ej value between zero and one.

$$E_j = -K \sum_{i=1}^{m} P_{ij} \times \ln P_{ij} \qquad i = 1,2, \ldots .m \qquad (2)$$

$$K = \frac{1}{\ln m}$$

3. The degree of deviation (dj) is determined based on the following calculation.

$$d_j = 1 - E_j \qquad (3)$$

4. Finally, the value of the criteria weight (Wj) is calculated according to the following formula.

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (4)$$

After weighing the decision criteria, one of the most recent multi-criteria decision-making methods, called weighted aggregated sum product assessment (WASPAS method), was used in this study. This method was proposed by Zavadskas et al. (2012) and was selected for this study due to its high accuracy caused by the combination of two multi-branch decision models of WSM (weighted sum model) and WPS model (weighted production model). The accuracy of this method is much higher than any of the aforementioned independent methods. The WASPAS model is one of the common models in complex decision problems.

1. In the first step, the decision matrix is normalized using the linear method through the following equation.

$$\overline{X}ij = \frac{X_{ij}}{Max_i\, X_{ij}} \quad (1)$$

2. Then the relative importance of the options was calculated based on WSM method using the following formula.

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{X}ij\, W_j \quad (2)$$

3. Also, the relative importance of the options was calculated based on WPM method using the following formula.

$$Q_i^{(2)} = \prod_{j=1}^{n} (\overline{X}ij)^{W_j} \quad (3)$$

4. Finally, based on formulas 3 and 4, the common criterion was calculated.

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} \quad , \quad \lambda = 0, \ldots 1 \quad (4)$$

In this research, the value of λ is equal to a fixed number of 0,5. Therefore, the value calculated in the final formula is as follows.

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5\sum_{j=1}^{n} \bar{X}ij\, W_j + 0.5\prod_{j=1}^{n} (\overline{X}ij)^{W_j} \quad (5)$$

According to the results, each option with a higher Q value has a higher score and priority. The main findings for the components prioritization section are as follows:

At first 11 experts in the oil and gas industry were scored from 1 to 9 in the decision matrix, and the decision matrix was then normalized as follows:

Table 5: Weighting prioritization criteria

Components \ Criteria	X1	X2	X3	X4	X5	X6	X7	X8
enterprise capabilities of technology transfer	0.921	1.000	1.000	1.000	0.990	0.982	1.000	0.792
Technological Capabilities and Resources	0.712	0.944	0.741	0.975	0.915	0.861	0.844	1.000
Independent technology commercialization business	0.687	0.788	0.758	0.975	0.655	1.000	0.699	0.711
Government policies of independent technology commercialization	0.746	0.585	0.715	0.834	0.842	0.845	0.570	0.687
Independent technology commercialization strategies at industry and enterprise	1.000	0.787	0.791	0.881	0.996	0.858	0.820	0.690
B2B interactions and partnership	0.475	0.534	0.859	0.753	0.901	0.621	0.748	0.878
Technology diplomacy and intellectual property rights	0.401	0.519	0.770	0.785	0.610	0.629	0.630	0.543
Nature and missions of transfer intermediaries	0.527	0.635	0.662	0.622	0.792	0.587	0.501	0.678
Capabilities of transfer intermediaries	0.669	0.851	0.969	0.973	1.000	0.807	0.621	0.642
Benefits of Independent technology commercialization	0.696	0.699	0.527	0.862	0.655	0.695	0.593	0.622

After normalizing the decision matrix, the criteria were weighted using Shannon's entropy method. The weighting information of each of the decision criteria is presented in the following table:

Table 6: Weighting prioritization criteria

Criteria / Weighting Dimensions	Profitability	Efficiency	The ability to internalize technology	Currency savings	Technology transfer between industries	Technology diffusion at the national level	Technological capability of oil industry	Technological synergy within the industry
Ej (The entropy of each index)	0.6992	۰.۷۲۰۵	۰.۶۴۶۴	۰.۷۰۰۲	۰.۶۴۵۰	۰.۷۰۴۹	۰.۶۹۹۹	۰.۶۸۸۲
Dj (Degree of deviation)	۰.۳۰۰۸	۰.۲۷۹۵	۰.۳۵۳۶	۰.۲۹۹۸	۰.۳۵۵۰	۰.۲۹۵۱	۰.۳۰۰۱	۰.۳۱۱۸
Wj (Normalized weight)	۰.۱۲۰۵	۰.۱۱۲۰	۰.۱۴۱۷	۰.۱۲۰۱	۰.۱۴۲۳	۰.۱۱۸۲	۰.۱۲۰۲	۰.۱۲۴۹

Finally, after calculating the relative significance of the options, the common criterion (Q) was calculated based on the WSM and WPM methods. Chart 1 shows the final result of prioritizing the options.

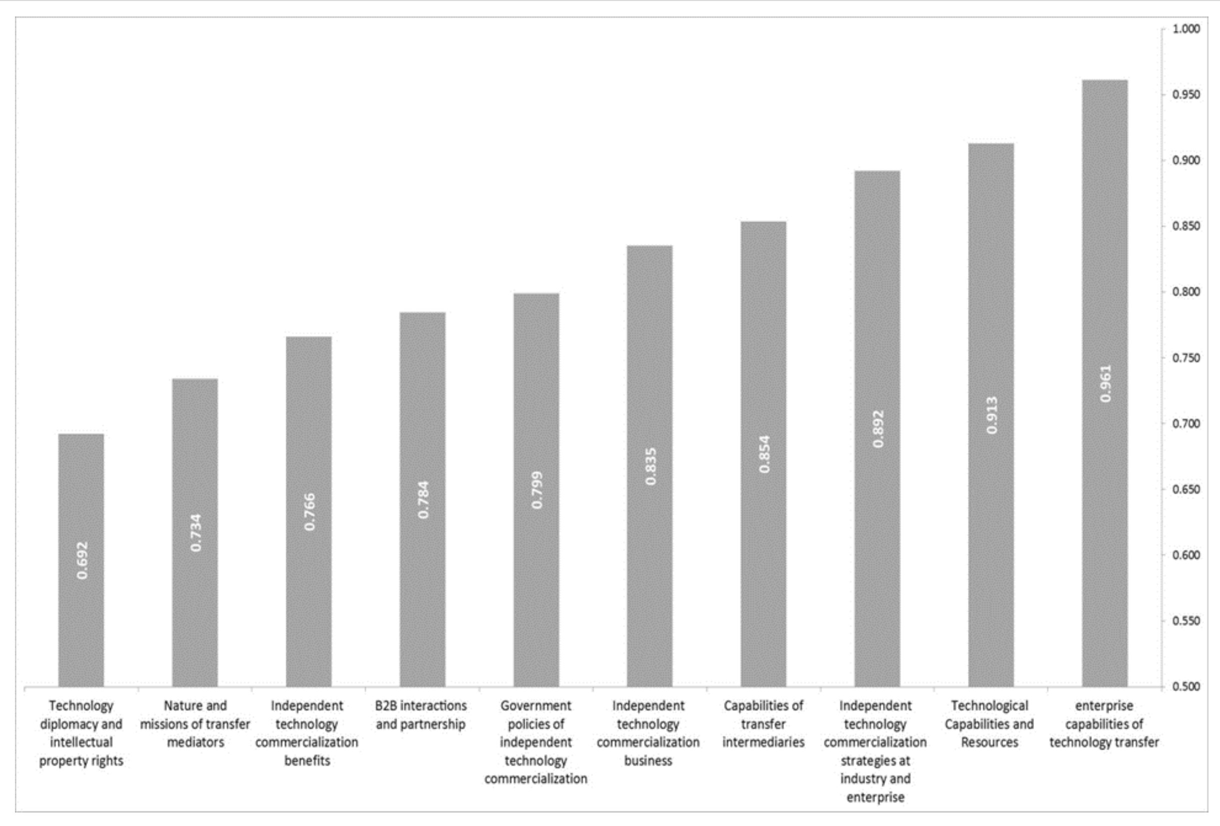

Figure 4: Prioritization of technology-independent commercialization components

According to the prioritization results, the enterprise capabilities of technology, technology capabilities, resources, and independent technology commercialization strategies were the first three priorities.

5. Discussion and conclusion

5.1. Discussion and suggestions

In this section, research discussions and suggestions are presented regarding the priorities of the components of independent commercialization of technology, as well as the indicators with the highest coefficient of determination.

5.1.1. Enterprise capabilities of technology transfer

According to the confirmatory factor analysis method, the component "organizational capabilities of technology transfer" has the highest factor load. Also in the WASPAS prioritization method, this component has the first priority in the commercialization of independent technology. Meanwhile, in the factor analysis of this component, the two indicators “Capability of technology documentation and knowledge transfer” and “Capability of identifying and analyzing market opportunities” have the highest analysis coefficient. Moreover based on the results of similar researches in the literature review, in most studies such as “Handbook on Technology Commercialization Practices in APEC Economies (2018), Saheed A Gbadegeshi(٢٠١٩) , Daniel K.N. Johnson, Kristina M. Lybecker(٢٠٠٩), G. Malek zadeh(2016), Dinmohammadi, M. Shafiee (2017), Jae-Woong Mina , YoungJun Kimb , Nicholas S. Vonortas (2020)” the indicator of market opportunity identification capabilities is mentioned and in a few studies (Ahmad Mousaei (2018)) the indicator of technological knowledge transfer has been identified.

In the present study, due to the focus on the concept of independent technology commercialization, the capability of analyze market opportunities is in order to identify technology customer needs to technology transfer to them, while in most similar research marketing is equivalent to identifying customers and end users of final products. In this regard, it is recommended that a special technology marketing mechanism be created separately from the marketing of products and services to transfer technology in the oil and gas companies because based on the analysis of available evidence, we see less specialized mechanism in the field of technology marketing with the aim of commercializing technology in the oil and gas industry.

This finding also confirms that regarding companies’ capabilities for independent technology commercialization in the oil and gas industry, “technical documentation and knowledge transfer” is critical. Accordingly, the present study recommends managers and policymakers in the oil industry to strengthen knowledge management and documentation of explicit and implicit knowledge and provide a suitable platform for registering and protecting personal and organizational knowledge in the field of key transferable technologies.

5.2. Independent technology commercialization strategies in the industry and enterprise

The second component with the highest factor loading is "independent technology commercialization strategies in the industry and enterprise", suggesting that it is virtually impossible to obtain successful results in technology commercialization without setting specific objectives and strategies at the macro level in the oil and gas industry and enterprises. This component has also been identified in the WASPAS prioritization method as the third component of independent technology commercialization. In this component, "the implementation of commercialization strategies" indicator had the highest coefficient of determination, explicitly suggesting that deployment of commercialization strategies are more effective than other indicators such as planning and strategic studies.

In this regard, the results obtained are similar to the research conducted by R. Bandarian (2013), Goodarzi (2012), M. Forouzandeh and M. Qadian (2015), Asghari.M and Rakhshanikia.M (2013) with the difference that in previous studies mainly to plan and develop commercialization strategies such as participatory, endogenous, and independent strategies in commercialization is emphasized and in the present study is specifically concerned with the implementation of commercialization strategies at both macro and micro levels.

Industry policymakers are thus recommended, while using the results of studies on the environmental factors of industry and enterprises, to develop macro-commercialization strategies and policies based on the concept of technology transfer in the context of independent technology commercialization. Furthermore, at the enterprise level, strategies and operational plans related to implementing the independent technology commercialization approach are expected to be planned and implemented in line with macro policies. In addition to promoting the strategic planning approach, policymakers at the macro level of the oil and gas industry are also recommended to pay special attention to implementing strategies after planning them. In this regard, as one of the duties of organizational governance, the implementation process of strategies and strategic plans is expected to be monitored to ensure their effective implementation continuously.

5.3. Technological capabilities and resources

According to other research findings, "technological capabilities and resources" component is the third component with a high factor load. Thus, technology's inherent features and attractiveness (both hardware and software features) are of great importance in independent technology commercialization. This component has also been identified in the WASPAS method as the second priority in the independent commercialization of technology. In this factor, "the technology life cycle" index has the highest coefficient of determination, indicating the high significance of understanding the technology life cycle before its commercialization. The importance of this indicator has been discussed in other similar studies such as G. Malek zadeh(2016), H.khodadad hoseini, R. sohrabi (2010), Jae-Woong Mina , YoungJun Kimb , Nicholas S. Vonortas (2020), Dinmohammadi, M. Shafiee (2017), zemlickiene (2020), Badegeshin (2019), Park (2019), Goodarzi (2012), Zahedi andMir Ghafouri (2017), Forouzandeh &Qadian (2015).

In similar studies, the life cycle indicator for technology acquisition and use in the production of new products (based on the definition of Markham (2004)) has been studied, while in the present study, understanding and analyzing the technology life cycle based on the concept of independent technology commercialization (on The basis of Khalil's definition) and with the aim of determining its position before transferring it to other organizations. It is recommended to perform the technology life cycle analysis approach in the oil and gas industry by tracing the trend of technology changes and also determine technological capabilities before transferring it to other organizations to identify the position of technology in stages such as emerging-maturity-growth and decline. In this way, understanding the technology life cycle is a prerequisite for the next commercialization steps like technology valuation and helps organizations make purposeful decisions in commercialization.

5.4. Capabilities of transfer intermediaries

The fourth important and highly influential component in technology commercialization in the oil and gas industry is based on confirmatory factor analysis and WASPAS prioritization method is "the capabilities of transfer intermediaries". These indicators point to the role of mediating for technology commercialization. The development of the capabilities of specialized mediators in the oil and gas industry and also the strengthening of the intermediation role of mediators have been emphasized in this research.

Similar studies have been done on this component, such as Clayton, Feldman, Lowe(۲۰۱۸), KarliHna Sari, Purnama Alamsyah, Anugerah Yuka (۲۰۱۷), Jae-Woong Mina , YoungJun Kimb , Nicholas S. Vonortas (2020), S. Houshmandi nia, N.Najafi zadeh (2018), S. Samadi, A. Kolahdoozan (2007) and E. Sadeghi (2016). In this regard, the indicator of capability of arbitrage/ intermediation services by technology transfer intermediaries has had the highest factor load. The result obtained from this section is in line with the definition Dalziel (2009) regarding the classification of technology transfer mediation services. Despite similar studies on the role of technology transfer mediators in commercialization, there is little evidence on the role of intermediation.

It is also recommended to design a precise executive mechanism in the companies affiliated with the Ministry of Petroleum to identify, interact, and cooperate with external technology transfer intermediaries and receive services from intermediaries in accordance with companies' level of capability. Moreover, due to enterprises' unawareness of market needs (target technology applicants) in the oil and gas industry, the capabilities of external intermediaries (mainly market technicians) should be used to introduce the technological capabilities of oil industry enterprises to other companies inside and outside the industry. This provides an appropriate opportunity to introduce technological achievements and to identify market needs. The implementation of the above proposal is subject to the establishment of a mechanism at the national level to identify companies' technological capabilities and introduce technology owners and applicants.

In addition to the above 4 priorities, the following priorities are briefly discussed below:

Another component in this research, i.e., "technology diplomacy and intellectual property rights", with the highest coefficient of determination encompassed the "recognition political factors in international technology transfer" indicator. In this regard, the success of independent commercialization, especially at the international level, similar to studies conducted by Mohammad Forouzandeh, Seyed Mehdi Qadian (2015). Finally, Hassan Safarlou, Mohsen Safarlou (2013) and Seyed Hamid Khodadad Hosseini, Ruhollah Sohrabi (2009), Dinmohammadi, M. Shafiee (2017) and Ravi, Manthan D, Janodia (2021) is highly dependent on diplomacy and international relations in the field of technology and understanding the requirements of intellectual property rights. In this regard, the present study suggests that independent technology commercialization should be considered an important issue at the level of international negotiations to develop cooperation with other countries.

In the factor "B2B interactions and partnerships", "the development of the external interactions" indicator has the highest impact coefficient, suggesting the importance of learning, networking, and understanding of technology ecosystems and innovation in improving technological capabilities. Hence, the oil and gas industry subsidiaries are expected to understand the role of external stakeholders in implementing independent technology commercialization in the form of a commercialization ecosystem and determine how to interact and the extent of external cooperation with them. This is also mentioned in Flag and Michael’s (2010) study. In line with Forouzandeh and Ghadian's (2015) findings, a balance between the maturity level of technology holder and recipient companies is one of the main issues having a significant effect on reducing risk and independent commercialization costs. Accordingly, the present study suggests that technology companies evaluate their technological gap with the applicant companies to minimize technology transfer risk before carrying out the independent technology commercialization process.

"The independent technology commercialization business" component is another factor influencing the commercialization process. This component refers to create and implementation of the technology commercialization process in the form of an independent business in an organization. Accordingly, commercialization is expected to be planned in the form of an independent business, i.e., independent of the organization's primary business. Regarding this factor, the "technology commercialization risk management" indicator has the highest coefficient of determination. In addition to the business model, it is essential to develop a business plan for the transfer and sale of technology to determine its justification, especially in the field of economic and marketing. In this way, it is possible to justify independent technology commercialization and simultaneously identify the risks of independent technology commercialization.

Further, under the "benefits of independent technology commercialization" component, the "acquisition of economic benefits of commercialization" indicator had the highest impact. In this regard, gaining economic benefits from commercialization should be a priority, and for this purpose, companies should first define their expected results in independent technology commercialization and then measure the effectiveness of the commercialization process based on economic achievements. In this regard, the present study proposes that specific budget resources should be allocated for the issue of independent technology commercialization, and its revenue should be forecasted in the framework of financial and economic planning of firms.

Finally, under the "government policy on independent technology commercialization" component, the “regulation of commercialization rules and regulations” indicator had the highest coefficient of determination. In this regard, relevant government agencies are recommended to identify the obstacles and problems of the current situation and, at the same time, formulate appropriate laws and regulations with a focus on removing legal barriers and restrictions, thereby facilitating the effective implementation of the commercialization approach.

6. Conclusions

This current study aimed to identify and prioritize independent technology commercialization components in the gas and oil industries. To this end, besides reviewing previous literature, 11 industry experts were interviewed. In this regard, 46 preliminary components categorized under ten dimensions were first extracted from the interviews with experts. Then, to confirm the obtained components, confirmatory factor analysis and structural equations were applied using SMART PLS software. Finally, 44 components were approved, and two components were removed. 52 managers and experts in oil industry research and technology developed and completed a questionnaire to perform structural equations. Thus, the most remarkable indicators of each component were determined according to the coefficients of determination (Table 1), indicating the share of the relevant index in explaining its component. Finally, the main components of commercialization were prioritized based on the WASPAS method.

According to the results of factor analysis and structural equations, "enterprise capabilities of technology transfer" had the highest factor loading and "independent commercialization strategies in industry and enterprise", "technological capabilities and resources", and "capabilities of transfer mediators" were prioritized next, respectively. Further, the results of component prioritization revealed the three factors of "enterprise capabilities of technology transfer", "technological capabilities and resources" and "independent technology commercialization strategies" as the first three priorities, respectively.

Technology commercialization based on the perspective of transferring technological capabilities to other companies and identifying new indicators of commercialization and also studding the role of technology transfer mediators in facilitating the process of independent technology commercialization as contribution of this research compared to previous research is considered. Finally, the suggestions presented in this study are mainly focused on creating new approaches and mechanisms for independent technology commercialization in oil and gas industries such as technology marketing, technology transfer competitors analysis, technology life cycle analysis before transfer, technological knowledge transfer and so on.

References

Arnaldi.S & Neresini.F, (2019), 'The role of intermediary organizations in the mainstreaming of Responsible Research and Innovation in the Italian industrial sector' Journal of Responsible Innovation, Volume 6, 2019

Ae-Woong.M, YoungJu.K, Vonortas.N, (2020), 'Public technology transfer, commercialization and business growth' European economic review, DOI: 10.1016/j.euroecorev.2020.103407

Akter, S., Fosso Wamba, S., & Dewan, S. (2017),'Why PLS-SEM is suitable for complex modelling? An empirical illustration in big data analytics quality', Production Planning & Control journal, Volume 28, 2017 - Issue 11-12

A.S. Mohamed, S.M. Sapuan, M.M.H. Megat Ahmad (2012), 'Modeling the technology transfer process in the petroleum industry:Evidence from Libya, Mathematical and Computer Modelling journal, Volume 55, Issues 3–4

Asghari.M and Rakhshanikia.M, (2013), 'Technology transfer in oil industry, significance and challenges', Procedia - Social and Behavioral Sciences 75 (2013) 264 – 271

Andrew Reamer with Larry Icerman and Jan Youtie, (2007), 'Technology Transfer and Commercialization', ECONOMIC DEVELOPMENT ADMINISTRATION

Benitez, J., Henseler, J., Castillo, A., & Schuberth, F. (2020), 'How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory is research', Information and Management journal

Bandarian, R, (2013), 'Strategies for implementation of commercialization and development of technology commercialization in the petroleum industry research institute', Journal of technology development management, Vol 1, Issue 2, Autumn 2013

Bandarian.R(2007),'Evaluation of commercial potential of new technology at the early stage of development whit fuzzy logic', journal of technology management and innovation, Vol 2, Issue 4

Chin, W.W., 1998. 'The partial least squares approach to structural equation modeling, in arcoulides', G.A. (Ed.), Modern Methods for Business Research. Erlbaum, Mahwah, pp. 295e358.

Daniel K.N. Johnson, Kristina M. Lybecker, (2009), 'Challenges to technology transfer: A literature review of the constraints on environmental technology dissemination' Department of Economics and Business Colorado College 14 E. Cache la Poudre Street Colorado Springs, CO 80903 July 29, 2009

Dinmohammadi, M. Shafiee, (2017), 'Determination of the Most Suitable Technology Transfer Strategy for Wind Turbines Using an Integrated AHP-TOPSIS Decision Model', Energies Journal, DOI: 10.3390/en10050642

Forouzandeh.M, Ghadian.M, (2015), 'Provide a model for technology transfer from research and development to industry in the defense industry'

Fornell, C. and Larcker, D.(1981); 'Evaluating Structural Equation Modeling with Unobserved ariables and Measurement Error', Journal of Marking Research

Goudarzi.M, (2012), 'Pattern of technology commercialization in Iranian government research institutes'

Gefen, D. and Straub, D.W. (2005). 'A Practical Guide to Factorial Validity Using PLS-Graph' Tutorial and Annotated Example. Communications of AISHenseler

Herlandí de Souza Andrade, Messias Borges Silva,(2017), 'Risk and Success Factors in

Technology Transfer' www.ijera.com/papers/Vol7_issue9/Part-1/G0709016671.pdf

Hooshangnia.S, Najafizadeh.N, (2016) ,'Future research of technology commercialization process and its methods in techno-mart, the platform of innovative technology exchanges'

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2018),' Multivariate Data Analysis' https://books.google.com/books?id=0R9ZswEACAAJ

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R. (2006).'Multivariate Analysis (6th ed.)', New Jersey: Pearson Education IncCronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika. 16, 297-334.

Hair, J.F., Ringle, C.M., 'Sarstedt, M., 2011. PLS-SEM: indeed a silver bullet', Journal of Marketing heory andPractice 19 (2), 139e151.

Handbook on Technology Commercialization Practices in APEC Economies (2018), APEC

Jason Li-Ying, (2012), 'What do we need from intermediaries for technology transfer to China? A European firm perspective Prometheus', Taylor & Francis Journals, vol. 30(2), pages 199-209, June.

J, & Fassott, G. (2011), 'Testing moderating effects in PLS path models', An illustration of available procedures. In Handbook of partial least squares.

Karlina Sari, Purnama Alamsyah, (2017), 'Critical Role of Intermediaries on Technology Transfer: Case Study of BIOTROP and Center for Mariculture Development of Lampung' Journal of Technology Management, DOI: 10.12695/jmt.2017.16.1.3

Kathleen R. Allen, (2012), 'Technology Commercialization: Have We Learned Anything?' The journal of engineering entrepreneurship

Khodadad hoseini, R, (2010), 'Techno-mart, the missing link in the management system and technology exchanges, designing and explaining a comprehensive model at the national level' Transformational Management Journal, Vol 1, Num 1

Shahabi.A, Moeeni.E, (2016), 'Modeling the role of academia and industry in technology transfer with a systems approach'

Safarloo.H, (2013), 'Strategic models for marketing and selling technology in the field of knowledge-based economy'

Mousaei,A, (2018), ' Designing a Specific Model for Technology Transfer in Oil, Gas, and Petrochemical Sectors' Petroleum Business Review

Minseo Kim, Hyesu Park, Yeong-wha Sawng and Sun-young Park, (2019),'Bridging the Gap in the Technology Commercialization Process: Using a Three-Stage Technology–Phroduct–Market Model', Sustainability 2019, 11, 6267. https://doi.org/10.3390/su11226267

Mehdizadeh.M, Raisins, (2011), 'Comparative comparison of the use of effective factors in technology transfer with MDCM approach (Case study of steel industry)'

Manoukian.A, Hassabelnaby,H and Odabashian,V, (2019) 'Technology Commercialization Review: Aiming at a fresher perspective based on partnership synergy, International Journal of Management Research & Review

Paige Clayton, Maryann Feldman and Nicholas Lowe, (2018), 'Behind the scenes: intermediary organization that facilitate science commercialization through entrepreneurship' Academy of Management Perspectives, Vol. 32, No. 1

Pradeep Srivastava Perspective, Sunita Chandra (2012), 'Technology Commercialization: Indian University', Journal of technology management & innovation, version On-line ISSN 0718-2724

Ravi.R, Manthan D. Janodia, (2022), 'Factors Affecting Technology Transfer and Commercialization of University Research in India: a Cross-sectional Study', Journal of the Knowledge Economy (2022) 13:787–803

Radfar.R, Khamseh.A, Madani.H, (2013), 'Technology commercialization is an effective factor in technology development and economy', Journal of science and technology parks and incubators

Sadeghi.E,Saadabadi.A, (2016), 'investigating the role of innovation mediators in the electronics industry'

Samadi.S, Kolahdoozan.A, (2007), 'Techno-mart, its place and function in the industrial and technological system'

Seo Kyun Kim, Bong Gyou Lee, (2011), 'The effect of R&D, Technology commercialization' Technological and economic development of economy, 2011 Volume 17(4): 563–578

Stephen M. Bauer, Jennifer L. Flagg, (2010), 'Technology transfer and technology transfer intermediaries' Assistive Technology Outcomes & Benefits (ATOB), Summer2010, Vol. 6 Issue 1, p129-150. 22p. 2 Diagrams, 3 Charts.

Vaida ZEMLICKIENĖ, Zenonas TURSKIS (2020),'Evaluation of the Expediency of Technology Commercialization', Technological and economic development of economy journal, DOI: https://doi.org/10.3846/tede.2020.11918

Zahedi.A, Mirghafuri.H, (2017), 'Mapping an integrated plan for developing the level of innovation and commercialization of Iranian knowledge-based companies using the approach of analysis and development of strategic options'