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Identifying and Prioritizing Technology Commercialization Components in Iran's Oil and Gas Industries

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ABSTRACT

Knowledge and technology can be used to gain business benefits in organizations. In this regard, in addition to using technology in the production of products, technology commercialization to transfer technology to other organizations is considered a practical approach to gaining business benefits. Accordingly, this study aims to identify and prioritize commercialization components in Iran's gas and oil industry to transfer technology to other industries and organizations since there is high potential 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 are detected and classified as 10 main components. Then, the confirmatory factor analysis method in SMART PLS software confirms the 44 attributes in 10 components. Shannon's entropy and WASPAS methods are 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 are identified: the "enterprise capabilities of technology transfer", "technological capabilities and resources", and "independent technology commercialization strategies in the oil and gas industry".

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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 previous studies, technology commercialization is considered the application of technology in producing products with fair prices and following market needs[5].

However, the present study focuses on the concept of "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 leading indicators. However, some industries in Iran have significant capabilities due to their long history of 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, technology commercialization based on the assignment of research achievements to organization developers has been used as such companies can ultimately gain the expected benefits. In other words, in the structure mentioned above, 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 toward revenue generation from technology transfer so that technology development can be partly funded in this way.

Moreover, the current situation can result from insufficient knowledge and understanding of the required capabilities in enterprises to commercialize the technology in the oil and gas industry. Accordingly, the present study seeks to answer two main questions: "What are independent technology commercialization components?" and "How are independent technology commercialization components prioritized?" This study aims 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 focuses 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. This study emphasizes the concept of independent technology commercialization to gain benefits from the sale and transfer of technology in the oil and gas industry. Some

[2] Goldsmith, 2003
[3] Thanh Huyen, 2009; Khalil, 2004
[4] Dhewanto, Vital and Sohal, 2009
[5] Thanh Huyen, 2009
[6] Document of strategic transformation of science and technology, macro goals, science, and technology system
[7] The new structure of oil industry research and technology

aspects of the novelty in this research are presented as described below.

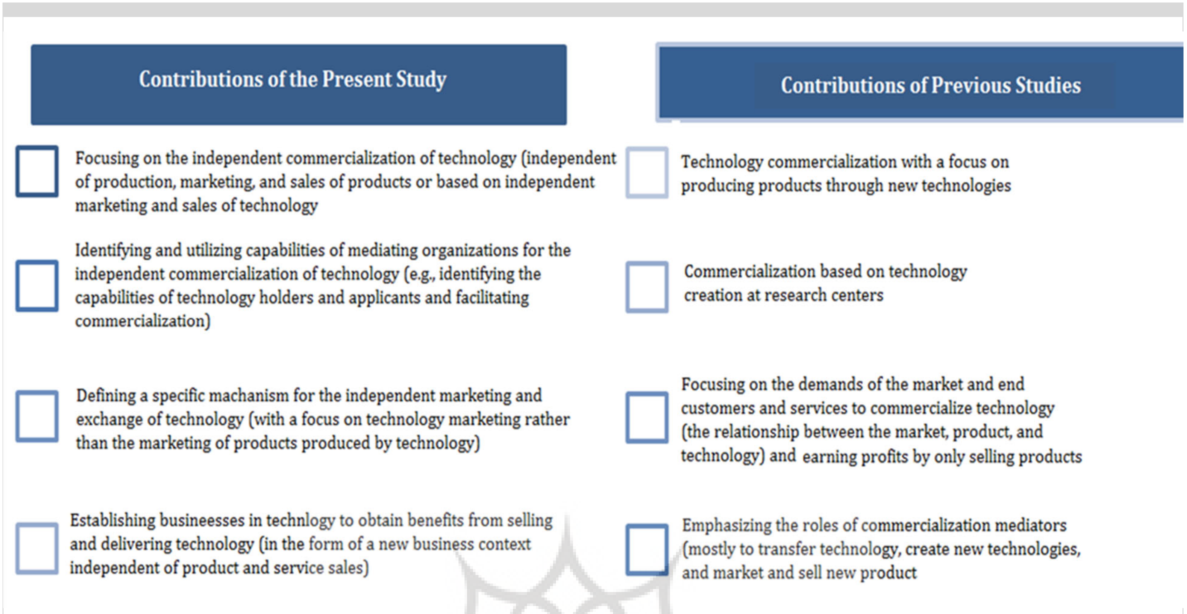

Figure 1: Comparing the present study with previous studies

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 standard 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 transforming technology into economical products. In another view, commercialization is equivalent to transferring and implementing 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 between 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 the commercialization process. In addition to 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 the sale and exchange of technology (as capital goods) in relevant and irrelevant industries. In this regard, commercialization can be defined as implementing technology in producing and selling products and technology marketing and 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 and the concept of *independent technology commercialization*. Moreover, the present study's approach to

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

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 literature review reveals that the commercialization components can be categorized into internal and external factors. Furthermore, some 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 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* is another critical factor in the *Asia-Pacific Commercialization Handbook* (2018) and Jae-Woong Mina, YoungJun Kimb, and Nicholas S. Vonortas (2020). Moreover, Malekzadeh (2015) and Kim[13] (2019) believed that understanding *customer needs* is a critical factor in commercialization success.

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 by Malekzadeh (2015) and Khodadad Hosseini, Sohrabi (2009), Dinmohammadi, M. Shafiee (2017), and Jae-Woong Mina, YoungJun Kimb, Nicholas S. Vonortas (2020). Meanwhile, Malekzadeh proposed recognizing the industry's technological challenges in commercialization as another influential factor (2015).

Another intraorganizational 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 and Lieber, 2009). Negotiability and capability to get under contract is another intraorganizational component introduced by Ahmad Mousaei (2018), Khodadad Hosseini, and Sohrabi (2009), as well as 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.

Other intraorganizational factors, 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 was 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 influential in the success of the commercialization process.

In addition to the above factors, the extra-organizational factors influential 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 played 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 were also raised as other factors by Bin (2012). The maturity level of the technology holder and receiver was another external factor in a paper published by Mohammad Forouzandeh and 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) considered intellectual property rights (IP) in commercialization an influential 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 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

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

technological intermediaries was discussed by Samadi and Kolahdoozan (2006). 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 technology commercialization, focusing on ICT technologies. Further, another study by Bandarian (2012) evaluated different factors in the commercialization of new technology. 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, its findings benefit policymakers and oil and gas industry managers. 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: the National Iranian Gas Company (NIGC), the National Iranian Oil Company (NIOC), and the National Iranian Oil Refining and Distribution Company (NIORDC). They are the policymakers and experts in the oil and gas industry, with their expertise in research and technology being 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 11 interviews were conducted to reach theoretical saturation. After the interview, 46 attributes were categorized under 10 main factors. Then, the confirmatory factor analysis and structural equations were calculated in SMART PLS software to confirm the obtained attributes. Finally, 2 attributes were removed, and 44 attributes were approved. This software was used for the following advantages: insensitivity to small sample size, insensitivity to abnormal data, the use of hybrid measurement models, actual ability to support moderating variables, ability to implement a researcher-made model, and the ability to use highly sophisticated models. To perform structural equations, we developed and submitted a questionnaire 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, this study assessed the validity of the collected data based on reliability tests, including Cronbach's alpha, composite reliability (CR), and commonality reliability. Furthermore, the study's validity was determined using the convergent validity test, divergent validity test, and measurement model quality test. Meanwhile, in analyzing the structural model (internal model) and its evaluation, the standard equation of R^2, Q^2, and the goodness of fit (GOF) of the general model was performed with SMART PLS software. Finally, MATLAB software calculated Shannon's entropy weighting method and the weighted aggregated sum product assessment method (WASPAS) to prioritize the identified components. For this purpose, the prioritization questionnaire was completed by 11 industry experts.

4. Findings

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

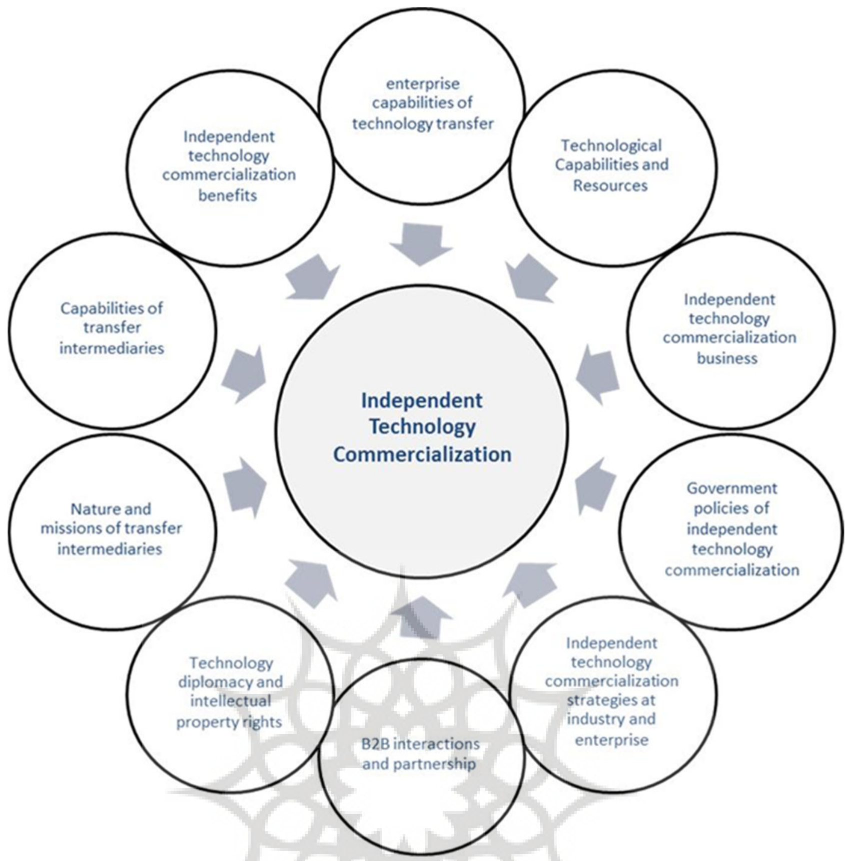

Figure 2: The critical components of independent technology commercialization (the research model)

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. Table 1 lists the factor loading of the commercialization indicators.

Table 1: The factor loading of the commercialization indicators

Components	Indicators	Variables code	Factor Loading
Enterprise capabilities of technology transfer (TT)	The capability to identify and analyze market opportunities	TT3	0.919
	The capability to identify the demands and expectations of technology applications	TT4	0.846
	The capability to analyze the data of technology competitors	TT6	0.754
	The capability of technology documentation and knowledge transfer	TT5	0.922
	The capability to evaluate technology and register patents	TT2	0.880
	The capability to negotiate and sign contracts	TT8	0.735
	The capability to localize and deploy technology	TT1	0.904
	The capability to support technology	TT7	0.865

Components	Indicators	Variables code	Factor Loading
Technological capabilities and resources(TC)	The capability to understand the 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 commercialization parties (i.e., the giver and receiver)	CI2	0.931
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

Components	Indicators	Variables code	Factor Loading
Capabilities of transfer intermediaries (IC)	The capability to provide the infrastructure and resources	IC1	0.717
	The capability to understand market demand and entrepreneurship	IC3	0.840
	The capability of arbitrage/intermediation services	IC2	0.859
	The capability to protect intellectual properties	IC5	0.835
	The capability to network and develop national and international interactions	IC7	0.809
	The capability to provide technical information and knowledge	IC6	0.744
	The capability to transfer and acquire 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

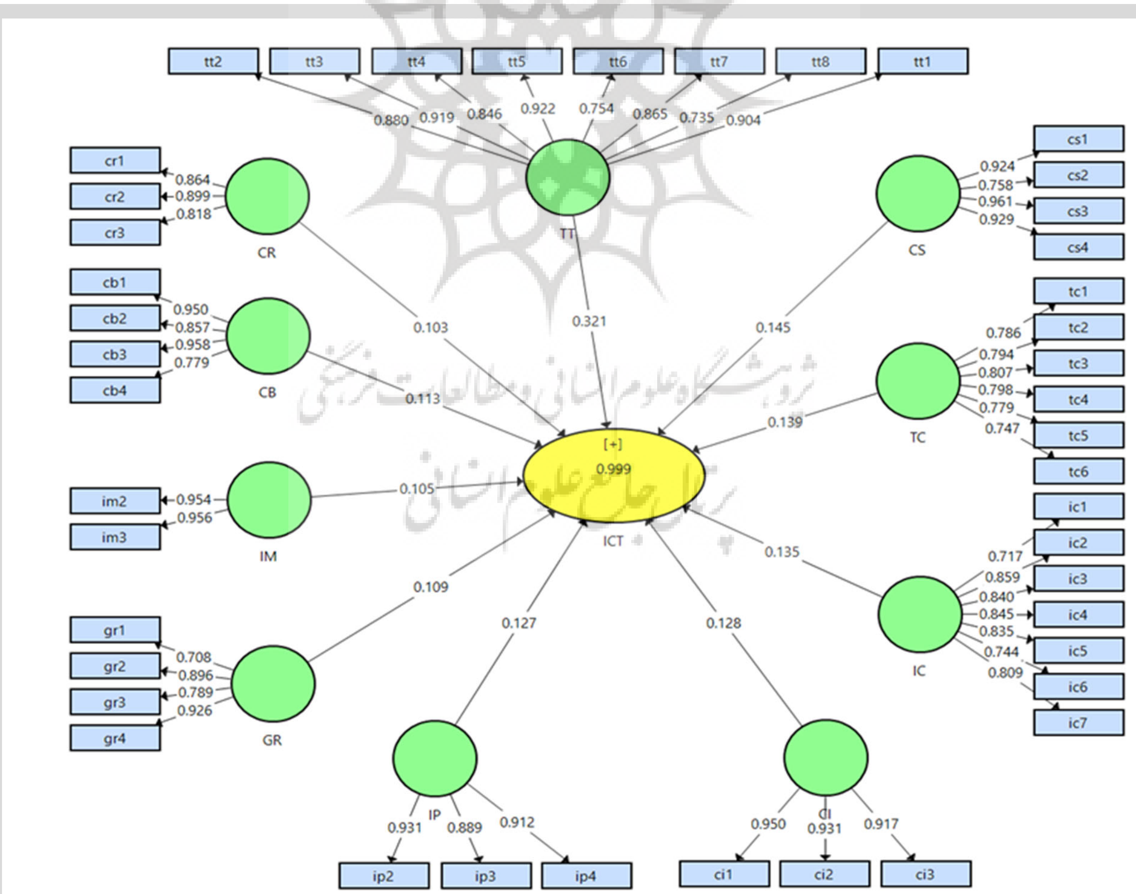

Figure 3: Corrective measurement model in the mode of estimating standard coefficients (loading factor)

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

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 higher than 0.7, and the extracted average variance must be higher than 0.5. As presented in Table 2, Cronbach's alpha for all factors is less than 0.7, confirming the model's reliability. Considering that the appropriate value for Cronbach's alpha and composite reliability is 0.7 and 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.

Further, 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 higher than 0.5, so the convergence validity of the data is confirmed. On the other hand, to confirm the convergence validity, CR must exceed the average variance extracted (AVE) (CR > AVE). As presented in Table 2, CR in all latent variables was higher than AVE (CR > AVE), so the convergent validity condition was satisfied.

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
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 commonality 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) showed that 0.15 and 0.35 were the medium and solid 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

Table 3 determines the high quality of commercialization indicators in this research. The coefficient of determination and predictive relationship test was used to analyze the structural model. The coefficient of determination always ranges between 0.0 and 1.0, 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 R^2 indicates how much the independent variables together predict the behavior of the dependent variable (Hair, 2018). The obtained R^2 value in this study is 0.999. The predictive correlation test (Q^2) 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 Q^2 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

The WASPAS method was used to prioritize the commercialization components, and Shannon's entropy method weighed each of the prioritized criteria. Prior to prioritization, independent technology commercialization dimensions were explained based on a meeting with 11 oil and gas industry experts, and 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 a 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: The segmentation of the 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 the 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 the 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 may be more or less significant than others, the weight of each criterion was determined using the abovementioned method according to the following steps.

1. The decision matrix is formed based on criteria and decision options. Then, the decision matrix is normalized, and the following calculation obtains the *Pij*.

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

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

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

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

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

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

4. Finally, the criteria weight (*Wj*) value is calculated using 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, the weighted aggregated sum product assessment, 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, the weighted sum model (WSM) and the weighted production model (WPM). The accuracy of this method is much higher than any of the aforementioned independent methods. The WASPAS model is one of the standard models in complex decision problems.

1. The decision matrix is normalized using the linear method through the following equation in the first step.

$$\overline{X}ij = \frac{X_{ij}}{Max_i\, X_{ij}} \quad (5)$$

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

$$Q_i^{(1)} = \sum_{j=1}^{n} \bar{X}ij\, W_j \quad (6)$$

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

$$Q_i^{(2)} = \prod_{j=1}^{n} (\overline{X}ij)^{W_j} \quad (7)$$

4. Finally, the standard criterion was calculated based on Equations (7) and (8).

$$Q_i = \lambda Q_i^{(1)} + (1-\lambda) Q_i^{(2)} \ , \quad \lambda = 0, \dots 1 \quad (8)$$

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.

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5 \sum_{j=1}^{n} \bar{X}ij\, W_j + 0.5 \prod_{j=1}^{n} (\overline{X}ij)^{W_j} \quad (9)$$

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 the 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 decision criterion is presented in Table 6.

Table 6: Weighting the prioritization criteria

Weighting Dimensions \ Criteria	Profitability	Efficiency	The ability to internalize technology	Currency savings	Technology transfer between industries	Technology diffusion at the national level	Technological capability of the oil industry	Technological synergy within the industry
Ej (The entropy of each index)	0.6992	0.7205	0.6464	0.7002	0.6450	0.7049	0.6999	0.6882
dj (Degree of deviation)	0.3008	0.2795	0.3536	0.2998	0.3550	0.2951	0.3001	0.3118
Wj (Normalized weight)	0.1205	0.1120	0.1417	0.1201	0.1423	0.1182	0.1202	0.1249

Finally, after calculating the relative significance of the options, the standard criterion (Q) was calculated based on the WSM and WPM methods. Figure 4 shows the final result of prioritizing the options.

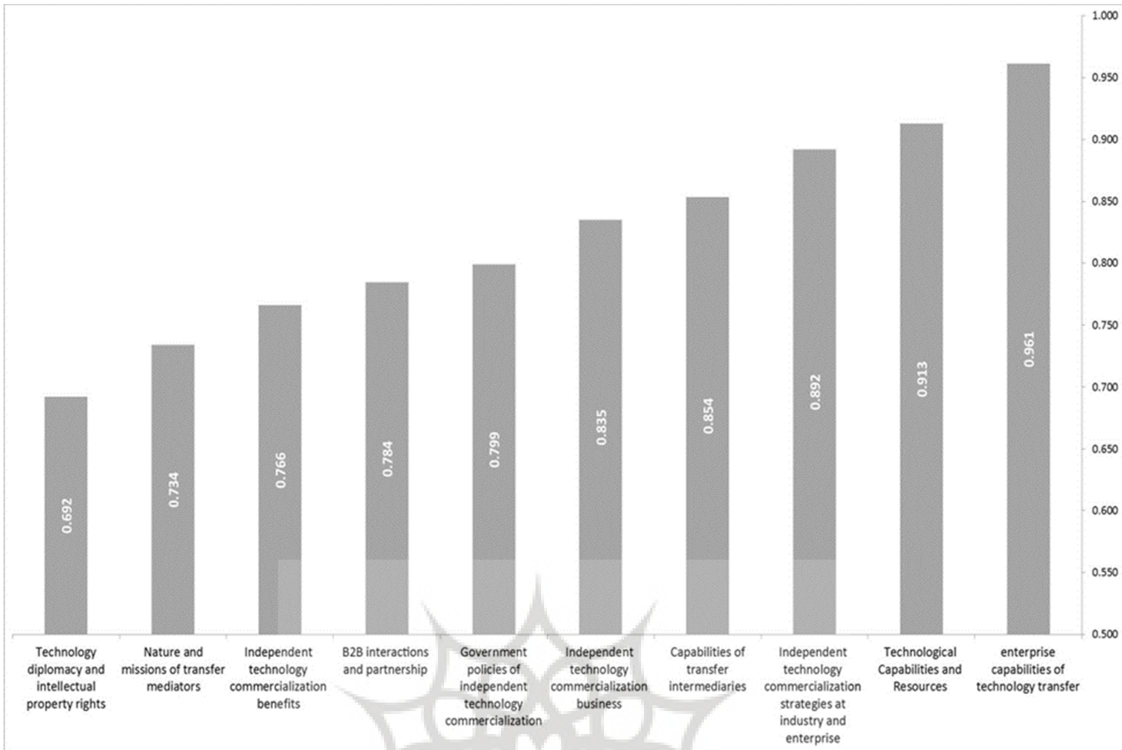

Figure 4: Prioritizing the technology-independent commercialization components

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 conclusions

5.1. Discussion and suggestions

This section presents research discussions and suggestions regarding the priorities of the components of independent commercialization of technology and the indicators with the highest coefficient of determination.

5.1.1. Enterprise capabilities of technology transfer

According to the confirmatory factor analysis method, the "organizational capabilities of technology transfer" component has the highest factor load. Moreover, in the WASPAS prioritization method, this component has priority in the commercialization of independent technology. Meanwhile, in the factor analysis of this component, the two indicators of "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 research in the literature review, most studies such as *Handbook on Technology Commercialization Practices in APEC Economies* (2018), Saheed A Gbadegeshi (2019), Daniel K.N. Johnson, Kristina M. Lybecker (2009), G. Malek Zadeh (2016), Dinmohammadi, M. Shafiee (2017), Jae-Woong Mina, YoungJun Kimb, Nicholas S. Vonortas (2020) mention the indicator of market opportunity identification capabilities, and the indicator of technological knowledge transfer has been identified in a few studies (e.g., Ahmad Mousaei (2018)).

In the present study, due to the focus on independent technology commercialization, the capability to analyze market opportunities is to identify customers' needs to transfer technology to them. At the same time, in most similar research, marketing is equivalent to identifying final product customers and end users. In this regard, it is recommended that a particular 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 a less specialized mechanism in the field of technology marketing to commercialize the 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, "technology documentation and knowledge transfer" is critical. Accordingly, the present study recommends that managers and policymakers in the oil industry strengthen knowledge management and documentation of explicit and implicit knowledge and provide a suitable platform for registering and protecting personal and organizational knowledge in 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", indicating 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, implying that the deployment of commercialization strategies is more effective than other indicators, such as planning and strategic studies.

In this regard, the results obtained are similar to the research of R. Bandarian (2013), Goodarzi (2012), M. Forouzandeh and M. Qadian (2015), Asghari.M and Rakhshanikia M (2013). It should be noted that previous studies mainly focus on planning and developing commercialization strategies such as participatory, endogenous, and independent strategies in commercialization. In contrast, the present study emphasizes implementing 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 for 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. As one of the duties of organizational governance, the implementation process of strategies and strategic plans is expected to be monitored to ensure continuous effective implementation.

5.3. Technological capabilities and resources

According to other research findings, "technological capabilities and resources" is the third component with a high factor load. Thus, technology's inherent features and attractiveness (both hardware and software) are essential 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 and Mir Ghafouri (2017), Forouzandeh and 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 the present study examines understanding and analyzing the technology life cycle based on the concept of independent technology commercialization (on the basis of Khalil's definition) and determining its position before transferring it to other organizations. It is recommended that the technology life cycle in the oil and gas industry should be analyzed by tracing the trend of technology changes. Technological capabilities should be determined before transferring them 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 the 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 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 (2018), KarliHna Sari, Purnama Alamsyah, Anugerah Yuka (2017), 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 of 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 of the role of intermediation.

Designing a precise executive mechanism in the companies affiliated with the Ministry of Petroleum is also recommended to identify, interact, and cooperate with external technology transfer intermediaries and receive services from intermediaries following the 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 four priorities, the following are briefly discussed.

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, is similar to studies conducted by Mohammad Forouzandeh and 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) have been 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 "B2B interactions and partnerships" factor, the "development of the external interactions" indicator has the highest impact coefficient, suggesting the importance of learning, networking, and understanding 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, balancing the maturity level of technology holders and recipient companies is one of the main issues that significantly reduce risk and independent commercialization costs. Accordingly, the present study suggests that technology companies should 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 creating and implementing the technology commercialization process as an independent business in an organization. Accordingly, commercialization is expected to be planned as 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 economics 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 simultaneously 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 identified and prioritized independent technology commercialization components in the gas and oil industries. To this end, 11 industry experts were interviewed besides reviewing previous literature. In this regard, 46 preliminary components categorized under 10 dimensions were first extracted from the interviews with experts. Then, confirmatory factor analysis and structural equations were applied using SMART PLS software to confirm the obtained components. Finally, 44 components were approved, and 2 components were removed. Fifty-two 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, 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, identifying new commercialization indicators, and studying the role of technology transfer mediators in facilitating the process of independent technology commercialization are considered the contribution of this research compared to previous works. Finally, the suggestions presented in this study mainly focus 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 the transfer, and technological knowledge transfer.

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