

Petroleum Company's Technology Commercialization Mode and Evaluation of Commercial Potential Based on Two-tuple Linguistic

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Abstract

The development of Petroleum Company and technology innovation are inseparable. Because of the lack of commercialization operation, a large number of technologies exist as the hidden assets in our country's Petroleum Company. It's important to explicit of tacit technology. Through analyzing Petroleum Company's technical features and manifestation and considering the current situation of petroleum industry's development, the paper put forward the technology commercialization's mode for our country's Petroleum Company. Further analysis shows that the commercialization process needs a key technology screening under the premise of limited resource. Based on these, the paper established the evaluation system of Petroleum Company's technology commercialization potential with two-tuple linguistic.

Keywords: *Petroleum Company; technology commercialization; evaluation of commercial potential; two-tuple linguistic*

1. Introduction

The capital and technology-intensive characteristics of oil industry determine that the important position and function of technological innovation in the development of oil industry. Especially in today's rapid development of science and technology, petroleum technology has become the main driving force of oil industry's development, and also be the main methods to improve economic efficiency. China's Petroleum Technology has experienced a transition from the track to imitate innovation. Especially with the proposal of China Petroleum Technology Development Strategy, which concrete content is "strengthen the development of core technology with independent intellectual property rights, concentrated on tackling the technical bottlenecks in major engineering research, enhance support of scientific and technological in overseas business, strengthen basic research [1]", the technological level of China's oil companies has been improved rapidly after 2000. However, the technology itself is an elusive intangible asset. The achievement of its economic value is influenced by many non-technical factors. Technologies' economic value can be reflected in concrete only after been commercialized [2]. If there is a lack of way to identify new technology commercialization, the business advantages in scientific research will not translate into advantages in technology commercialization [3]. Therefore, a lot of technological achievements which are formed in China's oil companies in exploration and development process can only exist in the manner of hidden assets due to lack of commercialization process. This is not conducive to the spread of technology transfer within the enterprise and outside the enterprise. So, Petroleum companies must pay attention to technology integration and regard technology commercialization as the center work to enhance enterprise competitiveness in science and technology.

This paper will be based on the characteristics and the manifestation of oil companies' technical, express non-quantifiable evaluation information by two-tuple linguistic and establish a more comprehensive evaluation system of technology commercialization potential. Then Petroleum companies can improve its efficiency by using the evaluation system to select key technologies which full of commercial potential.

2. Literature Review

At present, foreign research on technology commercialization is comprehensive, and studies are transforming from qualitative to quantitative, as Walter K it [4], illustrated the effect of factors of technology commercialization through quantitative analysis based on the studies NASA's sub-agencies' commercialization and technology transfer. SoYoung Sohn[5] studied on factors of technology commercialization's success from three aspects: the technology itself, technology recipient, and technology providers. Yongtae Park[6] measured commercial value of evaluation techniques through characteristics of technology and its commercial application. Schwartz and Carlos[7] researched on the optimal decision of new technology investment based on R&D and technology acquisition.

After introducing the concept of technology commercialization, domestic scholars proposed the connotation of new technology commercialization. Wang Jiwu, Huang Lucheng and Lu Wenguang[8] hold the opinion that the potential of emerging technologies commercialization is the untapped capabilities and latent energy contained in technology before it been commercialized. In other word, it is the possibility of a new technology to achieve economic profits and social benefits from the lab to the marketplace.

With the idea of technology commercialization becomes mature, more and more people apply this thought to different fields, including oil industry. China's oil companies contact technology commercialization later than companies abroad. Therefore, research on petroleum technology commercialization is not deep enough. With the continuous progress of petroleum enterprises' science and technology, many problems like technology transfer have cropped. Some scholars set out to study on countermeasure research. Wang Faming, Tong Zheng and Mao Jianqi [9] put the concept of emerging technologies into energy industry's policy research, and advised to raise the commercial success rate in the field of energy industry. Li Jinlan [10] sorted out different aspects of low-carbon technologies' commercial potential, includes connotation, classification, process, business indicators and evaluation, and study can provide more scholars with important reference value. Liu Chaoqun [11] used AHP and DEMATEL methods respectively to assess factors affecting the commercialization of renewable energy technologies. They also got more scientific research findings and recommendations by integrating the two methods. Yan Na, Ye Haichao and Di Weina [12] applied the idea technology commercialization to the field of petroleum engineering based on previous studies. They regarded the dual properties of technical goods and assets as a starting point, constructed selection matrix used in technology commercialization's mode, and gave suggestions to the oil companies. Zhang Li [13] searched the characteristics of commercialization of petroleum science and technology achievements combining with technical tangible case, and then specifically introduces tangible process. But so far, research on technology commercialization potential evaluation method of oil industry is rarely. This knowledge system needs to be improved gradually through further research.

3. Petroleum Enterprise's Technology Commercialization Content and Process

3.1 Characteristics of Petroleum Enterprise' Technology

Technical characteristics of China's oil companies are mainly in the following four aspects.

Technique involves a wide range of fields. It is not only includes geophysical prospecting, well logging, drilling, completion, ground engineering, petroleum engineering technology and oil refining, petrochemical refining technology, but includes equipment manufacturing, materials, automation control and other supporting technologies and assistive technology, *etc.* This development model makes areas of technology and technology of China's three major oil company become very complex. The degree of technical exchange and sharing are so weak that is not conducive to concentrate resources for technical breakthroughs. Also easily lead to some duplication of research and development of individual technologies.

Technology maturity period is long. Despite the technological level has improved, it still costs petroleum companies about 5 to 10 years to make the technologies apply practical[14]. Although the level of China's petroleum technology at or near the international advanced level in some areas, but it is difficult to obtain directly relevant technical information and parameters in some critical areas of technical. Companies must rely on self-development to achieve a breakthrough, which will extend the technology development period.

The level of hidden technology dominance is low. Veronique and Cliff [15] put the technology into the dominant technology, hidden coding technique, partially hidden coding technology and deep rooted hidden technology based on technology's unspeakable degree, and then pointed out that the implicit technology is unique, difficult to transfer, imitation and alternative. China's oil companies prefer to focus more on mastering and refining dominant technology rather than hidden technology. However, implicit Technology like experience, skills and technical skills rooted in the minds of technicians and specialists play a vital role in the actual technology diffusion process [16]. The development of commercialization process of China's petroleum enterprises is slow because the lack of explicit treatment with standardization.

Technical property right relationship is complex. Case with China National Petroleum Corp, its subsidiary include exploration and development company, oil and gas companies, refining companies, marketing companies, natural gas and pipeline transportation companies, overseas companies, engineering and technical services company, construction companies, equipment manufacturing companies, research institutes and other ten categories. There are several companies under each category. From the company perspective, the technology property is unity. But it will be more complex and sensitive when it comes to the specific interests of the different interests of the subject.

3.2 Manifestations of Petroleum Enterprise' Technology

From the characterization technology point of view, Chinese oil enterprises' technology can be divided into three categories: application of technology, equipment and software.

Application techniques include geophysical prospecting, well drilling, logging, perforating, trial mining, production engineering, laboratory analysis, surface engineering, *etc.* Range of equipment including drilling equipment, workover equipment, oil test equipment, logging equipment, operating equipment, fracturing equipment, wash well equipment, logging well testing equipment, interpretation equipment, motor type, transport vehicles, *etc.* Software including exploration and development and pipeline systems (Such as exploration and production technical data management systems, data management systems and gas wells, pipelines production management system, geographic

information systems, production engineering and ground transportation management systems, digital basin systems and engineering technology production operation management system), refining chemicals and sales systems (such as refining and chemicals operation system, refining the material optimization and scheduling system, gas management systems, customer relationship management system), Business support systems (such as e-procurement, sales, logistics systems, *etc.*) and integrated management systems (such as ERP systems, emergency management systems, office management systems, records management systems, internal management systems, health and safety and environmental protection systems, *etc.*).

On the one hand, oil companies must transfer the hidden technology into explicit technology as soon as possible so that it can convert to business efficiency; On the other hand, the wide ranges of fields in oil companies bring new business opportunities. Therefore, how to select technology with commercial potential will become the company's future development priorities.

3.3 The Connotation of Petroleum Enterprise Technology Commercialization

Broad sense of commercialization generally refers to the process which is develops from the research on product theoretical to industrial production. From a narrow perspective, commercialization process mainly contains technical transfer and profit creation. The process of technology transfer is at the center stage of the generalized commercialization process. Some scholars have pointed out that the essence of the commercialization is the process from idea to technology and product, and also from the lab to the market [5-9]. Wang Jiwu, Huang Lucheng and Lu Wenguang [9] proposed potential of commercialization of emerging technologies refers to energy and function implied in emerging technologies before proceeding with the commercialization.

According to the existing definition of commercialization proposed by scholars, the paper put forward the definition of petroleum enterprise's technology commercialization. The concept is that the process petroleum corporation successfully developed innovative technologies with market potential, and then exposes technologies to market after technology transfer, and ultimately creates profits for the company. Commercial potential of petroleum enterprise technology means the degree of difficulty and likelihood of petroleum enterprise's technology commercialization.

3.4 The Process of Petroleum Enterprise's Technology Commercialization

Technology commercialization of China's oil companies should follow the general technology commercialization process [9]. Domestic and foreign scholars have done a lot of useful research on technology commercialization steps. However, due to the complexity of the technology itself, there has not a completely unified understanding. There is a study that divides the technology commercialization process into five stages like theory, scientific discovery, laboratory feasible, pilot production and commercial promotion [17]. Some scholars think that the general technology commercialization process should go through six stages, which include technological research, technology development, technology transfer, product concept development, production and sales and technology commercialization success [18]. In a word, despite the different partitioning method, from the operation of the track, the technology commercialization process is nothing more than the process from the idea to the technology, to large-scale applications, and in other words, from the laboratory to the market.

The paper will divide the process of commercialization into six stages combined with the petroleum enterprise's technical characteristics and the background of application. The production of technical requirements is the first stage, which due mainly to the breakthrough of basic theory or the problems faced by production practice. For example, along with the increasing difficulty of exploitation of resources, Daqing Oilfield

breakthrough in polymer flooding theory, and successfully developed a salt polymer flooding technology and ASP flooding technology. The second stage is the technical research and development. Various departments of Petroleum Enterprises combine their technology needs and cooperate with relevant research institutes to seek a breakthrough method. The next one the stage is testing and demonstrating technologies. Technical departments will do industrial test based on previous studies, and improve technology through exemplary application in a range of sectors. After that, the fourth phase is technique extension within the company. Specifically, the companies will carry out technical tangible process, establish standardized technical standards, technical processes and technical specifications, and then form a summary technical manuals which lay the foundation for the commercialization of technology. The fifth stage is called technology commercialization potential evaluation stage. In this stage, the company should evaluate various types of technologies of petroleum enterprise and select technologies with high technical content and significant gains. Finally, do market promotion. Petroleum companies can achieve technology commercialization by the following ways. They can complete technology transfer through domestic or international technology market, or authorize patented and proprietary technology to other companies, and they can also participate in the exploration and development of oil and gas resources abroad in the way of technology shares. Figure 1 summarizes the above six stages.

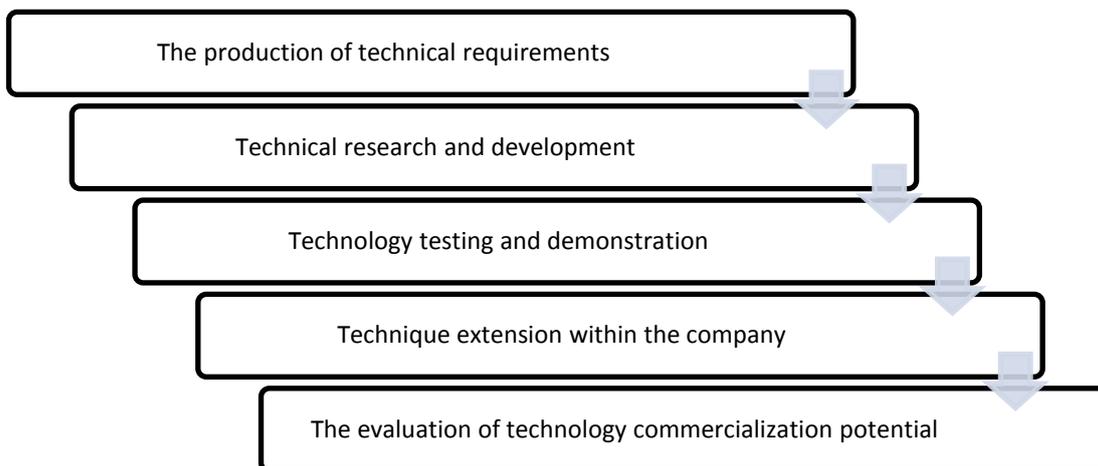


Figure 1. The Process of Petroleum Enterprises' Technology Commercialization

4. Construction and Application of the Evaluation Model

4.1 Evaluation System of Petroleum Enterprises' Technology Commercialization Potential

The oil industry is a technology-intensive industry, each firm produce a large number of new technologies applied to the production practices every year, but these techniques are not all suitable for commercial operation. What's more, it is limited in terms of the company's human, financial and material resources so that only a few technologies can be commercialized within a period. Therefore, in the process of oil enterprise technology commercialization, much of the technologies only applied within company, only high-potential technologies will be ultimately commercialized and marketed.

For this, the paper constructs the evaluation system of China petroleum enterprise technology commercialization potential, which is combining technological development and practice of Chinese petroleum companies and index system of technology selection

overseas, and also gives the evaluation algorithm based on two-tuple linguistic.

Judging whether a technology has commercial potential is not only depending on the advanced nature of the technology itself, but also focus on the examination of infrastructure conditions and market demand, and then measure synthetically combined with the technology in-house application effects.

The evaluation index system of China Petroleum Enterprise technology commercialization potential proposed by the paper is divided into four levels, which are the basic indicators, technical indicators, market indicators, outcome indicators. Each level select specific evaluation based on Questionnaire survey and data collection (Shown in Table 1). Since many evaluating indexes are difficult to fully quantify and qualitative analysis alone does not beneficial to the final screening, the paper use two-tuple linguistic method to deal with evaluate indicators which are difficult to quantify.

Table 1. Evaluation System of Petroleum Enterprise's Technology Commercialization Potential

Evaluation index	Index details	Measurable indicators	Data form
Basic indicators	Human resource	Staffing	Linguistic value
	Financial	Financial support	Linguistic value
	Material	Material support	Linguistic value
Technical indicators	Advancement	The capability of technology substitution	Linguistic value
		Leading technology degree	Linguistic value
		The potential for the formation of industry standards	Linguistic value
		The number of patent	Numerical value
	Consistency	The consistency of national industrial policy	Linguistic value
		The consistency of international technology trends	Linguistic value
		The consistency of market demand at home and abroad	Linguistic value
	Maturity	Development stage	Linguistic value
		Reliability	Linguistic value
Market indicators	Customers' loyalty degree	International client	Numerical value
		Domestic customer	Numerical value
	Market entry	Market potential	Linguistic value
		Market barriers	Linguistic value
	Uniqueness	The number of competitors	Numerical value
Market awareness		Linguistic value	
Outcome indicators	Economic benefits	Input-output ratio	Numerical value
		financial internal rate of return	Numerical value
	Technical effect	Changes in production capacity	Numerical value
		Changes in labor efficiency	Numerical value
		Savings in resource use	Numerical value
	Social benefit	Job creation	Numerical value

4.2 Evaluation Model

4.2.1 Algorithm steps: Let $P = \{P_1, P_2, \dots, P_q\} (q \geq 2)$ be the set of evaluation index, where P_j represents the j-th index; Let $E = \{E_1, E_2, \dots, E_m\} (m \geq 2)$ be the set of expert, where E_k represents the k-th evaluators. Suppose that $R^k = (r_1^k, r_2^k, \dots, r_q^k)^T$ is the weight vector of index set given by expert E_k , where r_j^k is selected by expert E_k from the linguistic evaluation set which is defined previously. The linguistic evaluation set S is defined as:

$$S = (s_0, s_1, s_2, s_3, s_4) = (\text{very high}, \text{high}, \text{medium}, \text{low}, \text{very low})$$

Let $H = \{H_1, H_2, \dots, H_f\} (f \geq 2)$ be the set of technology, where H_j means the k-th technology. Suppose that $A_i^k = (a_{ij}^k)_{n \times q}$ be the linguistic assessment matrices given by E_k , where a_{ij}^k is an element selected by expert E_k from the linguistic evaluation set S, which represents the evaluation value of P_j in terms of H_i .

The steps of algorithm proposed by the paper are as follows:

(1) Calculate the weight of each evaluation index.

a. Transform the weight matrix of index $R^k = (r_1^k, r_2^k, \dots, r_q^k)^T$ into 2-tuple linguistic evaluation matrix $\hat{R}^k = (\hat{r}_1^k, \hat{r}_2^k, \dots, \hat{r}_q^k)^T$, where $\hat{r}_j^k = (r_j^k, 0)$.

b. Aggregate each expert's evaluation information by using the following

$$\hat{r}_j = \Delta \left[\frac{1}{m} \sum_{i=1}^m \Delta^{-1}(r_j^i, \alpha_j^i) \right] = (r_j, \alpha_j) \quad (1)$$

We can get a comprehensive view of the whole evaluation team for each index weight through the two sub-steps above.

(2) Compute group evaluation.

a. Transform the linguistic assessment matrices $A_i^k = (a_{ij}^k)_{n \times q}$ into 2-tuple

$$\hat{A}_i^k = \left(\hat{a}_{ij}^k \right)_{n \times q}, \text{ where } \hat{a}_{ij}^k = (a_{ij}^k, 0)$$

b. Synthesis expert's evaluation information by using the following formula.

$$\hat{a}_{ij} = \Delta \left[\frac{1}{m} \sum_{k=1}^m \Delta^{-1}(a_{ij}^k, 0_{ij}^k) \right] = (a_{ij}, \alpha_{ij}) \quad (2)$$

c. As for numeric index value, we choose the method normalization processing using the formula:

$$\hat{a}_{ij} = \frac{a_{ij} - \min(a_{ij})}{\max(a_{ij}) - \min(a_{ij})} \quad (3)$$

(3) Define the positive ideal point and the negative ideal point.

According the definition of ideal point, let P^+ be the positive ideal point, and let P^- be the negative ideal point. The calculation formulas of positive/negative ideal point are as follows.

$$P^+ = (P_1^+, P_2^+, \dots, P_q^+), q \geq 2 \quad \text{where } P_j^+ = \max\{a_{ij} \mid i = 1, 2, \dots, f\} \quad (4)$$

$$P^- = (P_1^-, P_2^-, \dots, P_q^-), q \geq 2 \quad \text{where } P_j^- = \min\{a_{ij} \mid i = 1, 2, \dots, f\} \quad (5)$$

(4) Calculate the distances between each technical indicator and the positive/ negative ideal point.

The distance between the positive ideal point and each technical indicator is calculated by the formula:

$$d_{ij}^+ = |a_{ij} - p_j^+|, i = 1, 2, \dots, f$$

(6) The distance between the negative ideal point and each technical indicator is calculated by the formula:

$$d_{ij}^- = |a_{ij} - p_j^-|, i = 1, 2, \dots, f \quad (7)$$

(5) Rank the technological according to distance.

According to the evaluation ideological of ideal point method, technology evaluation value will be high if it is near the positive ideal point while farther away from the negative ideal point. Calculated as follows:

$$d_i^* = \sum_{j=1}^q (d_{ij}^+ - d_{ij}^-)r_j, i = 1, 2, \dots, f \quad (8)$$

Through above method, it can better identify a single technology or technology series of the oil companies which have higher commercial value inside. Petroleum Enterprises can prioritize the commercialization of related technologies according to the evaluation so that oil companies can get greater returns and benefits under the premise of technology ownership.

4.2.2. Application Model: One petroleum company wants to evaluate five technologies ($A = \{A_1, A_2, A_3, A_4, A_5\}$) and select one technology whose commercial potential is greater than others. The company hires experts to evaluate each index of the evaluation system. Numerical indicators are expressed in digital, such as the number of patents, technology effectiveness and input-output ratio. To measure indicators which cannot be quantified, assessors need select from the assessment information given by experts based on their experience, such as social effects and the stage. Company gets expert's reviews using the questionnaire form. In order to improve the accuracy of evaluation information, the average of the evaluation information is regarded as the final result. Obtain the final weight of evaluation index through comprehensive treatment. As shown in Table 2.

Table 2. The Weight of Evaluation Index

Evaluation index	Index details	Measurable indicators	Weights	
Basic indicators	Human resource	Staffing	Important	3
	Financial	Financial support	Important	2.8
	Material	Material Support	Important	2.6
Technical indicators	Advancement	The capability of technology substitution	Important	2.6
		Leading technology degree	Important	3
		The potential for the formation of industry standards	General	2.2
		Original range	General	2.4
		The number of patent	General	1.8

	Consistency	The consistency of national industrial policy	General	2.2
		The consistency of the company's development strategy	Important	3
		The consistency of oil company's development plan	Important	2.8
	Maturity	Development stage	General	2.25
		Reliability	Important	3
Market indicators	Customers' loyalty degree	International client	General	1.6
		Domestic customer	General	2.2
		Group internal customers	Important	2.8
	Market entry	Market potential	General	2.4
		Market barriers	General	1.75
	Uniqueness	The number of competitors	General	2.25
Market awareness		Important	3	
Outcome indicator	Economic benefits	Input-output ratio	Important	3
		Financial internal rate of return	Important	2.75
	Technical effect	Changes in production capacity	Important	2.5
		Changes in labor efficiency	General	2.25
		Savings in resource use	Important	2.5
	social benefit	Job creation	General	2.25
		The effects on people's health	Important	2.5
		The impact on harmonious social	General	2.25
		The impact on related industries	General	2
		The impact on the natural environment	General	2.25

According to Table 1, experts give different weight of each index in different technologies, which is reflecting the importance of indexes in terms of each technology. Follow the steps of the algorithm mentioned in 4.2.1, and then obtain the results. As is shown in Table 3, the priorities of technologies explain that A_3 is the best suitable to commercialize.

Table 3. Evaluation Results of Oil Companies

Priorities	Technology	The results
1	A_3	112.9115
2	A_2	112.3415
3	A_1	112.3321
4	A_5	112.2325
5	A_4	112.0455

5. Conclusion

The paper puts forward the definition of Petroleum Enterprise's Technology Commercialization. Based on the technical features and manifestations of the oil companies, pointing out the key aspects of Petroleum company's technology research and development lies not only in innovation, but also in the commercialization of the results of the prior art. On the basis of analyzing the Petroleum business goals and technology commercialization model, the paper proposed the basic steps in the petroleum business for technology commercialization, and constructs the evaluation system of oil companies' technology commercialization potential, and uses the algorithm to solve practical problems.

Acknowledgment

Supported by Humanity and Social Science Youth Foundation of Ministry of Education in China (Project No. 10YJC630104).

Supported by Youth Talent Plan of Beijing Municipal Education Commission (Project No. YETP0690).

Supported by Science Foundation of China University of Petroleum, Beijing (Project No. KYJJ2012-08-18).

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