Research on Tangible Indexes of Petroleum Engineering Technology

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Abstract. The active effort on the tangibility of petroleum engineering technology is of important significance to the improvement of technological impact and commercial application of oil and gas technology. The evaluation index system for tangibilization of petroleum engineering technology is determined on the basis of technological tangibilization practice of domestic and foreign oil companies. The evaluation system mainly includes four dimensions: market demand factor, technological maturity factor, commercial application factor and business development demand factor. The different dimensions have different variables. The factor analysis method is adopted to calculate the weight of each variable index. Based on examination of credibility and validity, this indexes system is shown to have a good questionnaire structure, facilitating acquisition of respondents’ information and guiding petroleum engineering technological service companies to evaluate whether their own technology needs to be tangibilized.

1. Introduction
The concept of technology tangibility was first proposed by China National Petroleum Corporation. It refers to changing technologies, products, matching processes, software, services, solutions, rules of experience and other physical or non-physical things into a kind of ability that can be copied, produced and published through standardization, normalization, organization, integration and other knowledge management methods. It results in the change of technologies that are scattered, implicit and dependent on a small number of experts into shareable and inheritable explicit technologies, and forms a technological brand through a variety of effective carriers and means, which is beneficial for enhancing the core competitiveness and maximizing the value of technology[1-2]. In a broad sense, technology tangibility covers sound, image, picture, text and environment recognition systems that can reflect technology. It is an important content and main carrier of science and technology culture construction[3].

Petroleum engineering technology service enterprises have a large number of independently developed engineering technologies, and the technology management department has already recognized the importance of technology tangibility. However, the current problem is that not all technologies have reached tangible conditions. How to screen tangible technology is a problem urgently needed to be deeply researched. For this purpose, a set of tangible technology evaluation indexes system is developed to estimate the tangible needs of petroleum engineering technologies and to select suitable technologies for tangibilization.

2. Design of petroleum engineering technology tangible indexes screening system
The research scope of the tangible technology screening system for petroleum engineering industry is focused on matching technologies, special technologies and single technologies. Matching technologies
are a collection of technologies that can take on the heavy responsibility of oil and gas exploration and development. Special technology is a technology in one petroleum engineering specialty, and a single technology is a technology that can solve a single problem in petroleum engineering. The purpose of this study is to establish a set of screening indicators for tangible technologies. The system design is based on the principles of high maturity, maximization of market potential, and urgent business needs.

The study was standardized according to the evaluation system development process standards proposed by Bagozzi in 1991 (Figure 1) [4]: First, determining the scope of petroleum engineering technology evaluation; second, refining the evaluation indicators, mainly based on the company’s petroleum engineering business; the third is to seek interviewers’ opinions on the evaluation index system through open questions, and complete the addition and selection of indicators after full discussion. Addition and screening should follow the following principles: indicators are closely related to the business of the enterprise, which are in the technology areas that enterprises are most concerned about, and have practical significance. Based on this principle, this study selected three survey indicators after three discussions in the research group.

![Figure 1. Design process of technology tangibility screening index system.](image)

### 3. Determination of screening index and weight for tangibilization of petroleum engineering technology

#### 3.1. Questionnaire design and preliminary survey

In order to select indicators scientifically and reasonably, a questionnaire survey is adopted in the process of understanding the situation. The content of the questionnaire consists of two section. The first section, which is the main part of questionnaire and comprises of 7 questions (Table 1), surveys respondents’ evaluation and perception of the tangible influence factors of petroleum engineering technology, and thus provides supports for data collection and model research. The technology tangibility was first defined before answering the questions. This section uses Likert's 7-level scale. 1 means "strongly disagree" and 7 means "strongly agree". Respondents make choice according to their own professional knowledge and experience. The second section of the questionnaire is to survey the personal information of the respondents, including their age, title, and years of experience in the petroleum engineering industry.

| Num | Contents                                                                 |
|-----|--------------------------------------------------------------------------|
| V1  | The tangibilization of petroleum engineering technology is the need of the company's internal market |
| V2  | The tangibilization of petroleum engineering technology is the need of the company's external market |
| V3  | The tangibilization of petroleum engineering technology is affected by technological maturity |
| V4  | The tangibilization of petroleum engineering technology is needed for commercial application |

Table 1. List of tangibility screening and evaluation questions of petroleum engineering technology.
3.2. Samples and data

This study obtained data through interviews with experts and questionnaires, which are qualitative. The questionnaire survey is designed according to the index system. In order to ensure the quality of the questionnaire, the questionnaires are distributed by the members of research team, and the surveys are conducted face-to-face.

A total of 103 experts in the field of petroleum engineering technology were contacted during the research and investigation phase. After screening, 103 valid questionnaires were identified, and the effective rate was 100%. The composition of the respondents to the effective questionnaire is shown in Table 2. The composition of the research sample reflects the overall composition of the respondents, and has a strong representation.

| Classification index | number of people | Percentage (%) |
|----------------------|------------------|----------------|
| Gender               |                  |                |
| Male                 | 73               | 70.8           |
| Female               | 30               | 29.2           |
| Age                  |                  |                |
| 18~25 years old      | 4                | 3.8            |
| 26~35 years old      | 32               | 31.2           |
| 36~45 years old      | 48               | 46.6           |
| Over 45 years old    | 19               | 18.4           |
| Title                |                  |                |
| Intermediate         | 26               | 25.2           |
| Senior               | 72               | 69.9           |
| Professor            | 5                | 4.9            |

3.3. Exploratory factor analysis

The factor analysis estimation uses the principal component method, and the rotation method is the varimax rotation. The factor analysis load results are shown in Table 3. The KMO statistic of factor analysis is 0.938> 0.7, and the analysis effect is very good. Then the Bartlett spherical test gives a concomitant probability of 0.000, which is less than the significant level of 0.05. It shows that the assumption of independence of each variable is not valid. The data passed the factor analysis applicability test, which shows that the questionnaire has fairly good construction validity.

The eigenvalue, variance contribution rate, and cumulative contribution rate are calculated from the sample correlation coefficient matrix R (Table 4). It can be seen that the variance of the first factor accounts for about 48% of the variance of all factors, and the second factor accounts for 8%. By analogy, the variance contribution rate of the first four factors is close to 78.3%. It can be considered that most of the information in the variables is extracted, and the first four factors are sufficient to describe the information related to technology tangibility.

| Question Items                                                                 | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Communalities (%) |
|--------------------------------------------------------------------------------|----------|----------|----------|----------|-------------------|
| 1. The tangibilization of petroleum engineering technology is the need of the company's internal market | 0.748    | —        | —        | —        | 81.1              |
2. The tangibilization of petroleum engineering technology is the need of the company's external market 0.858 — — — 76.5

3. The tangibilization of petroleum engineering technology is affected by technological maturity — 0.834 — — 75.6

4. The tangibilization of petroleum engineering technology is needed for commercial application — — 0.799 — 83.2

5. The tangibilization of petroleum engineering technology is the need for technology inheritance and internal sharing — 0.642 — — 81.9

6. The tangibilization of petroleum engineering technology is the need of the company's development planning — — — 0.704 78.5

7. The tangibilization of petroleum engineering technology is the need for the development of main business — — — 0.834 74.1

| Table 4. Variable cumulative contribution rate |
|-----------------------------------------------|
| Factor | Initial eigenvalue | Shaft square and load |
|        | Sum | Variance ratio (%) | Cumulative contribution (%) | Sum | Variance ratio (%) | Cumulative contribution (%) |
| 1      | 0.851 | 4.319 | 67.22 | 1.703 | 8.963 | 52.766 |
| 2      | 0.772 | 4.012 | 71.232 | 1.651 | 8.689 | 61.454 |
| 3      | 0.699 | 3.613 | 74.845 | 1.642 | 8.644 | 70.098 |
| 4      | 0.66  | 3.423 | 78.268 | 1.552 | 8.17  | 78.268 |

The seven factors extracted by factor analysis, which are listed in Table 3, are named as follows according to the literature and their characteristics: the first factor (items 1 and 2) is the market demand factor; the second factor (items 3 and 5) is the technological maturity factor; the third factor (item 4) is a commercial application factor; the fourth factor (items 6 and 7) is a business development demand factor.

3.4. Credibility test
The most commonly used Cronbach's α coefficient is used to evaluate the credibility of the samples. The Cronbach’s α coefficient of the entire questionnaire is 0.934, which indicates that the questionnaire has good reliability and stability. The Cronbach's α coefficients that make up each factor's items exceed 0.7, which shows that the internal consistency of these factors is very good. The statistical results are shown in Table 5.

| Table 5. Cronbach’s α coefficient |
|-----------------------------------|
| Latent variable                  | Number of questions | Cronbach’s α |
| Market demand factor             | 2                  | 0.878        |
| Technology maturity factor       | 2                  | 0.854        |
| Commercial application factor    | 1                  | 0.872        |
| Business development demand factor | 2              | 0.716        |
3.5. Validation Test
The Bartlett test showed that the construction validity of the items of each factor of the questionnaire was good. Exploratory factor analysis obtained 4 factors from 7 reduced variables, and the cumulative variance contribution rate was 79.8%. The aggregation validity test was performed on the variables in each factor. The results showed that the variables included in each factor only converged on one common part with eigenvalues greater than 1. The minimum explanation proportion of factor to variance also reached 73%, indicating that the seven reduced variables have good convergent validity.

3.6. Weight setting: take the factor coefficient matrix as the weight
Factor score is the ultimate manifestation of factor analysis. After the factors are determined, the specific values of each factor on each sample can be calculated. These values are called factor scores, and the variables formed are called factor variables. In the subsequent analysis, you can use factor variables instead of the original variables to perform data modeling, or use factor variables to classify or evaluate samples, thereby achieving the goals of dimensionality reduction and problem simplification.

The way to calculate the factor score is to use the original variable to describe the factor. The value of the i-th factor on the j-th sample can be expressed as:

\[ F = w_{i1}x_{1j} + w_{i2}x_{2j} + w_{i3}x_{3j} + \cdots + w_{ip}x_{pj} \]  

In the formula, \( i = 1, 2, 3, \ldots, k \); \( x_{1j}, x_{2j}, x_{3j}, \ldots, x_{pj} \) are the values of the 1, 2, 3, ..., p-th original variables on the j-th sample; \( w_{i1}, w_{i2}, w_{i3}, \ldots, w_{ip} \) are the factor coefficients between the i-th factor and the 1, 2, 3, ..., p-th original variables, respectively. Therefore, it is the result of the linear combination of the original variables. The factor score can be regarded as the weighted sum of the values of the variables. The magnitude of the weight indicates the importance of the variable to the factor. This study used regression to estimate the factor score coefficients, and used the factor score coefficients as weights to get 4 factor scores for each sample (Table 6).

| Index             | Market demand | Technology maturity | Commercial application | Business development demand |
|-------------------|---------------|---------------------|------------------------|-----------------------------|
| External market   | 0.19          | —                   | —                      | —                           |
| Internal market   | 0.16          | —                   | —                      | —                           |
| Technology maturity | —            | 0.23                | —                      | —                           |
| Commercialize     | —             | —                   | 0.18                   | —                           |
| Internal sharing  | —             | —                   | —                      | 0.07                        |
| Development plan  | —             | —                   | —                      | 0.05                        |
| Business needs    | —             | —                   | —                      | 0.12                        |

Aiming at the needs of petroleum engineering technology service companies for their own technologies to be tangibilized, a set of evaluation indexes system for tangibilization of petroleum engineering technology was developed using factor analysis, cluster analysis and other methods in strict accordance with the development process of the index system. This index system has good reliability and validity, which can objectively reflect the degree of tangibilization demand for technology of oil service companies. Its greatest value lies in helping and guiding oil service companies to evaluate and screen whether their own technology needs to be tangibilized.

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