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Research Article

Multi-Criteria Decision-Making Approach for Analyzing Competency Model of Technology Managers

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The economies of all the countries are growing with the passage of time. In order to promote the businesses in the global markets, technology managers/technical brokers play a key role such as in the optimal allocation of scientific and technological resources. The industrialization of scientific and technological achievements is also possible due to optimal utilization of resources and a balance between exports and imports. The technology managers should be competent enough to bridge the gaps between the resource requirements and the availability of the resources required to run the businesses smoothly. This paper is using multi-criteria methods for analyzing the qualities in the technical managers which can assist the managers to run the businesses in an efficient manner to compete in the global markets. The interviews and questionnaire are used to collect the primary data. The opinion of experts is also considered. Then, SPSS 22.0 statistical analysis software is used to analyze the reliability and validity of the factors considered in the questionnaire. Then by using statistical techniques, a quantifiable competency model of technology managers is constructed. The multi-criteria AHP (analytical hierarchical process) method is used to compare the competency characteristic indexes of each level in pairs and quantitatively describe their importance of the criteria. It also assigns weights to judge the importance of each competency characteristic index. Since the evaluation of technical managers' competency will be affected by various factors as mentioned in the paper, the fuzzy comprehensive evaluation method is also used to transform the evaluation dimension to accurately evaluate the competency of the technical manager which assists to judge the effectiveness of model evaluation. The proposed method provides theoretical and practical basis for the selection, evaluation, and cultivation of technical managers. It provides accuracy in results by 94% by adopting the statistical techniques.

1. Introduction

In order to implement the innovation-driven development strategy, China has revised and promulgated a series of policies and regulations such as the law on the promotion of transformation of scientific and technological achievements for accelerating the pace of technology for the technical managers. The new policies are promoting the development of factor markets and supporting the transformation of economic development models along with the optimization of structures of the organizations. It can be seen that the transformation of scientific and technological achievements is an important breakthrough for any country in the world to improve its comprehensive strength and to achieve leapfrog development [1]. However, science and technology are not directly related to the commercial market, but they are present at every walk of industry globally where every manual effort is getting replaced by the technology these days [2]. In order to equip the business with the global markets, technical advancements in the business are important and this role can be played by the technical managers [3].

In 2016, the term "technical manager" was first put forward in the action plan for promoting the transformation of scientific and technological achievements issued by the general office of the State Council in China. Technical managers refer to practitioners who take the transformation of scientific and technological achievements as their own responsibility and apply professional knowledge and practical experience to promote the commercialization and

industrialization globally [4]. In ancient times, the technical managers were termed as technical brokers. Foreign research on technical managers started earlier, and foreign scholars mainly focus on the management policies and service work of technical managers. For example, the USA passed the "Bayh-Dole Act" in 1980 to establish a technology transformation mechanism and cultivate technology brokers. The "Technology Transfer Commercialization Act" enacted in 2000 provides legal protection for technology brokers to work as service intermediaries [5]. In Japan, companies use R&D (research and development) funds every year to provide a strong financial guarantee for the technical services of the technology brokers [5]. In China, scholars focus their research on the status and role of technical brokers, as well as the quality and training of technical brokers. The researchers believe that technical brokers should have professional ethics, scientific literacy, ability to capture and screen information, and ability to organize and coordinate [6].

A research group led by McClelland explored the reasons for excellent work performance in technical managers to allow technical advancements in industries [7, 8]. McClellan believes that individual job performance depends more on some potential factors which can better predict individual performance in a specific job. He calls the personal characteristic that can distinguish the performance level of a specific job in the organizational environment [9]. Since then, the competency theory has been widely concerned by scholars in psychology, management, and other disciplines [10]. In [11], the author has constructed a general model of competency which includes six competency feature groups such as target and action management, human resource management, guidance to subordinates, attention to others, and knowledge. In [12], the competency of technical managers is based on multiple factors such as motivation, attitude or values, self-image, characteristics, knowledge in a certain field, cognitive or behavioral ability, and other individual characteristics that can distinguish excellent performance from general performance [12]. In [13], the author has paid attention to the public service management competency model of public managers by suggesting a model which includes task competency, entity policy and administrative competency, political competency, and ethical competency [13]. In [14], the author has taken up the lead in research of managers' competency in Chinese enterprises. The data are collected to analyze the behavior of family business executives through interviews and studied the characteristics of corporate executives' competence by building an executive competency model [14]. To sum up, existing research has begun to include the quality of technical managers but has not yet formed a model which can help to evaluate the competency of technical managers. This has motivated us to prepare a model based on multiple criteria for analyzing the competency of technical managers which provides basis for the evaluation of managers for global assignments. In this paper, author builds a model for ascertaining the technical managers' competency on the basis of multiple factors.

1.1. Highlights of the Proposed Study

1.1.1. Study Focus. By analyzing the recruitment advertisements and in-depth interviews of technical managers, the key competency characteristics of technical managers are initially extracted and then SPSS13.0 is used to test the reliability and validity of the questionnaire scale of technical managers' competency. A competency model of technical managers is developed to provide evaluation indicators and basis for experts to evaluate the competency of technical managers.

1.1.2. Estimated Achievements. Multiple factors are considered to analyze the competency of technical managers on the basis of multi-criteria decision-making model. The model is capable for comprehensively describing and extracting the competency characteristics of technical managers. This model is making use of the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method to evaluate the competency of technical managers. The multi-criteria analysis technique is given preference over the multi-objective optimization in order to reduce the time and space complexity of the proposed model.

The study contributes in developing a model based on multiple criteria for evaluating the competency of technical managers.

2. Construction of Competency Analytical Model

2.1. Questionnaire Design. The authors have pointed out that the technology managers require a competency model [15]. First, a questionnaire survey has been designed. In order to ensure the reliability and validity of the questionnaire, 21 recruitment advertisements for technical managers are arranged, the key words are screened out, and preliminarily determinants are found out. The content of the questionnaire is combined with the connotation of competency model and with the existing research.

2.1.1. Index Design

(1) Literature Analysis. Collect and study the literature on competency model and technical manager quality research at home and abroad, consult the competency dictionary, clarify the connotation of general competency and the requirements of technical manager competency, and then determine that the content of the questionnaire will cover five aspects: motivation, characteristics, self-concept characteristics, knowledge, and skills [16, 17].

(2) In-Depth Interview. Five technical managers were interviewed to guide the interviewees to describe the most unsuccessful and successful key events in their work. Then analyze the key factors, refine the key qualities of technical managers, and provide basis for the contents of the questionnaire.

2.1.2. Questionnaire Preparation. The content of the questionnaire consists of the competency characteristics of technical managers, their explanations, and options. After comparison, selection, and combination, 35 high-frequency competency items were selected and the competency items were arranged in the questionnaire for given corresponding explanations. Then, Likert five-point scoring was used to design five scores. The scores from "1" to "5" correspond to "unimportant," "less important," "general," and "more important." The five options of "very important," from low to high, require the respondents to judge the importance of each item.

2.2. Investigation Implementation. In December 2020, with the assistance of Guangdong University Scientific and Technological Achievements Transformation Center, a questionnaire survey was conducted among technical managers of universities, scientific research institutes and enterprises, human resources experts, and relevant scholars. In this study, 109 questionnaires were actually filled in and 109 were recovered, with a recovery rate of 100% of which the effective questionnaire was 109 copies, and the effective rate was 100%.

2.3. Data Statistical Analysis

2.3.1. Reliability Analysis. Internal consistency reliability test is the most commonly used reliability analysis method using Cronbach's alpha conduct internal consistency test for each dimension. At the beginning, the author classifies 35 competency items into 7 dimensions as shown in Table 1.

Then, Cronbach's alpha can be calculated by formula (αCoefficientαValue) to illustrate the reliability of the questionnaire data. The calculation formula is as follows:

$$a = \frac{n}{n-1}\left(1 - \frac{\sum_{i=1}^{n} s_t^2}{S_T^2}\right), \quad (1)$$

where n represents the number of all test items, which is the variance of the score of the question "i" and the variance of the total score of all tests.

The data are analyzed with SPSS22.0 statistical software, and the reliability test results of seven dimensions are shown in Tables 2 to 8.

The higher the coefficient is, the higher the reliability of the questionnaire. The coefficient >0.60 is acceptable, the coefficient between 0.70–0.98 has high reliability, and <0.35 has a lower reliability. It can be seen that the reliability of the questionnaire is good and the measurement results are reliable.

In addition, in order to ensure the credibility of the overall scale, the overall scale value is significantly higher than the original value after deleting a question item. Secondly, it should be considered to delete the question item if the overall correlation coefficient between the question item and the scale is low or negative. If both conditions are met, it should be deleted. This study conducts internal consistency test between the competency of each dimension and the total

Table 1: Competency dimensions and characteristic items.

Serial number	Dimension	Competency items
1	Achievement motivation	Enterprise Initiative Sense of adventure Enterprising spirit Dedication
2	Personal traits	Self-confidence and charisma Tenacity Sincerity Flexibility
3	Self-concept	Conscientiousness Service consciousness Emotion control time management Professional ethics
4	Decision-making ability	Market insight Ability to deal with emergency innovation ability Planning ability Strategic thinking
5	Public relation ability	Social ability Information capture and screening capabilities Networking Negotiation ability
6	Organization and communication skills	Team work ability organization skills Expressive ability Coordination ability Horizontal knowledge
7	Knowledge learning and application ability	Subject knowledge Technical manager expertise Continuous learning Research ability Demonstration and evaluation capability Document writing ability

Table 2: Reliability test results of seven dimensions.

Serial number	Dimensions	α coefficient	N of items
1	Achievement motivation dimension	0.656	5
2	Personal trait reliability	0.730	5
3	Self-concept dimension	0.693	5
4	Decision-making ability dimension	0.854	5
5	Public relation ability dimension	0.840	4
6	Organization and communication ability dimension	0.814	4
7	Knowledge learning and application ability dimensions	0.803	7

Table 3: Reliability test results of competency items of achievement motivation dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value α after item deletion
Enterprise	12.230	14.481	0.479	0.573
Initiative	12.218	13.312	0.562	0.529
Sense of adventure	12.126	19.391	−0.011	0.776
Enterprising spirit	12.092	13.410	0.496	0.560
Dedication	12.115	13.173	0.606	0.509

Table 4: Reliability test results of competency items of personal trait dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value α after item deletion
Self-confidence	12.138	16.237	0.556	0.657
Charisma	12.287	21.812	0.066	0.824
Tenacity	12.264	15.848	0.556	0.656
Sincerity	12.023	14.930	0.684	0.603
Flexibility	12.207	15.050	0.654	0.615

Table 5: Reliability test results of competency items of self-concept dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value after item deletion
Conscientiousness	11.747	14.773	0.516	0.613
Service consciousness	11.805	13.229	0.685	0.531
Emotion control	11.736	20.522	0.019	0.801
Time management	11.598	14.941	0.546	0.602
Professional ethics	11.782	14.638	0.550	0.598

Table 6: Reliability test results of competency items of decision-making ability dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value after item deletion
Market insight	11.782	21.266	0.669	0.825
Ability to deal with emergencies	11.483	24.253	0.589	0.844
Innovation ability	11.897	21.605	0.687	0.819
Planning ability	11.667	21.202	0.678	0.822
Strategic thinking	11.563	22.156	0.728	0.810

Table 7: Reliability test results of competency items of public relation competency dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value after item deletion
Social ability	9.011	12.732	0.695	0.787
Information capture and screening capabilities	8.920	12.889	0.648	0.808
Networking	8.943	13.939	0.642	0.81
Negotiation ability	9.126	12.368	0.708	0.781

Table 8: Reliability test results of competency items in the dimension of organization and communication ability.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value after item deletion
Team work ability	8.874	13.53	0.687	0.740
Organization skills	8.851	14.477	0.601	0.781
Expressive ability	8.885	13.498	0.65	0.757
Coordination ability	8.736	14.15	0.594	0.784

Table 9: Reliability test results of competency items of knowledge learning and application ability dimension.

Competency items	Scale average after deleting items	Scale variance after deleting items	Correlation between corrected items and total scores	Value after item deletion
Horizontal knowledge	18.483	33.927	0.697	0.747
Subject knowledge	18.368	33.282	0.727	0.741
Technical manager expertise	18.379	35.029	0.639	0.758
Continuous learning	18.287	34.533	0.642	0.757
Research ability	18.425	34.271	0.623	0.760
Demonstration and evaluation capability	18.322	34.825	0.628	0.760
Document writing ability	18.356	47.837	−0.107	0.877

table of this dimension. The test results are shown in Tables 3 to 9.

Value α of achievement motivation dimension is 0.656. After deleting the "risk awareness" indicator, the α value after deleting the item is 0.776 which is significantly improved and greater than the threshold value of 0.7. Therefore, this indicator is deleted. Table 4 shows reliability test results of competency items of personal trait dimension.

Value α of the personal trait dimension is 0.730. After deleting the "charisma" indicator, the value of the deleted item is 0.824 which is significantly improved and greater than the threshold value of 0.7. Therefore, this indicator is deleted. Table 5 shows reliability test results of competency items of self-concept dimension.

The value of self-concept dimension is 0.693. After deleting the "emotion control" indicator, the value after deleting the item is 0.801 which is significantly improved and greater than the threshold value of 0.7. Therefore, this indicator is also deleted. Table 6 shows reliability test results of competency items of decision-making ability dimension.

When the value of decision-making ability is 0.854, no significant increase is found in the deleted value. Therefore, all indicators are retained. Table 7 shows reliability test results of competency items of public relation competency dimension.

The value of the public relation capability dimension is 0.840, and no significant increase is found in the deleted value. Therefore, all indicators are retained. Table 8 shows reliability test results of competency items in the dimension of organization and communication ability.

The value of the organization and communication ability dimension is 0.814. After the item is deleted, no significant increase is found. Therefore, all indicators are retained. Table 9 shows reliability test results of competency items of knowledge learning and application ability dimension.

Table 10: KMO and Bartlett's spherical test results.

KMO sampling suitability quantity		0.859
Bartlett sphericity test	Chi-square value	1557.971
	Freedom	465
	Significance	000

The value of knowledge learning and application ability dimension is 0.803. After deleting the "official document writing ability" indicator, the value after deleting the item is 0.877 which is significantly improved and greater than the threshold value of 0.7. Therefore, this indicator is deleted.

2.3.2. Validity Analysis. Structural validity test is used to measure the degree of isomorphism between the actual evaluation results and the assumed evaluation characteristics [16]. Structural validity is generally determined through factor analysis; that is, the statistical method of extracting common factors from the variable group and dividing the variables with high correlation which is closely related to the same category [17, 18]. Each category of variables actually represents an essential factor, so that the original observation can be separated. The variables are expressed as a linear combination of new factors to present the basic structure of the scale [19, 20]. The analysis steps are as follows:

(1) Correlation Test. The validity of the questionnaire can be judged by the correlation between the KMO value and the Bartlett test. The test results are shown in Table 10.

KMO value is used to test the partial correlation between variables, and the value range is 0~1. When KMO value is

Table 11: Factor characteristic and variance interpretation rate.

Factor	Factor load before rotation			Factor load after rotation		
	Characteristic root	Variance solution release rate%	Cumulative variance interpretation rate%	Characteristic root	Variance solution release rate%	Cumulative variance interpretation rate%
1	12.186	39.308	39.308	3.412	11.005	11.005
2	1.967	6.346	45.654	3.383	10.912	21.917
3	1.753	5.655	51.309	3.049	9.836	31.753
4	1.531	4.939	56.249	2.975	9.597	41.351
5	1.307	4.216	60.464	2.860	9.226	50.577
6	1.228	3.961	64.425	2.764	8.915	59.492
7	1.089	3.513	67.938	2.618	8.446	67.938

Table 12: Project structure of essential factors of competency.

Competency items	Factor load						
	1	2	3	4	5	6	7
Enterprise							0.716
Initiative							0.655
Enterprising spirit							0.546
Dedication							0.618
Self-confidence							
Tenacity			0.694				
Sincerity			0.62				
Flexibility			0.718				
Conscientiousness			0.602				
Service consciousness							
Time management					0.713		
Professional ethics					0.761		
Market insight					0.591		
Ability to deal with emergencies		0.677			0.595		
Innovation ability		0.699					
Planning ability		0.636					
Strategic thinking		0.674					
Social ability		0.783		0.704			
Information capture and screening capabilities				0.623			
Networking				0.807			
Negotiation ability				0.711			
Team work ability							
Organization skills							
Expressive ability						0.680	
Coordination ability						0.547	
Horizontal knowledge						0.672	
Subject knowledge	0.651					0.727	
Technical manager	0.529						
Professional knowledge	0.568						
Continuous learning	0.648						
Research ability	0.778						
Demonstration and evaluation capability	0.648						

less than 0.5, it indicates that the observed variables are not suitable for factor analysis. When KMO value is closer to 1, it indicates that the correlation of each variable indicates that the reliability and validity are good and suitable for factor analysis. The results of KMO and Bartlett's test of sphericity show that the KMO value is 0.859, which is a high score. While the significance value of Bartlett's test of sphericity is 0.000, it indicates that there is a difference between the original variables. The data in the questionnaire are valid, and both methods as discussed above prove that factor analysis is suitable for the study.

(2) Principal Component Analysis (*PCA*). PCA is the most commonly used analysis method in factor analysis [2]. PCA is used to extract common factors with characteristic roots greater than 1. Then, in order to make the results easy to explain, the factor load matrix is rotated orthogonally with the maximum variance, and seven factors are extracted. The cumulative variance interpretation rate is 67.938%. Therefore, the structural validity of the questionnaire is good as shown in Table 11.

The essential factor structure of competency is shown in Table 12.

Table 13: Competency components of technical managers.

Competency dimension	Competency
Motivation	Dedication, initiative, enterprising spirit, and dedication
Personal traits	Confidence, tenacity, integrity, and flexibility
Self-concept	Sense of responsibility, sense of service, time management, and professional ethics
Decision-making ability	Market insight, ability to deal with emergencies, innovation ability, planning ability, and strategic thinking
Public relation ability	Social skills, information capture and screening skills, networking, and negotiation skills
Organizational and communication skills	Team work ability, organization ability, expression ability, and coordination ability

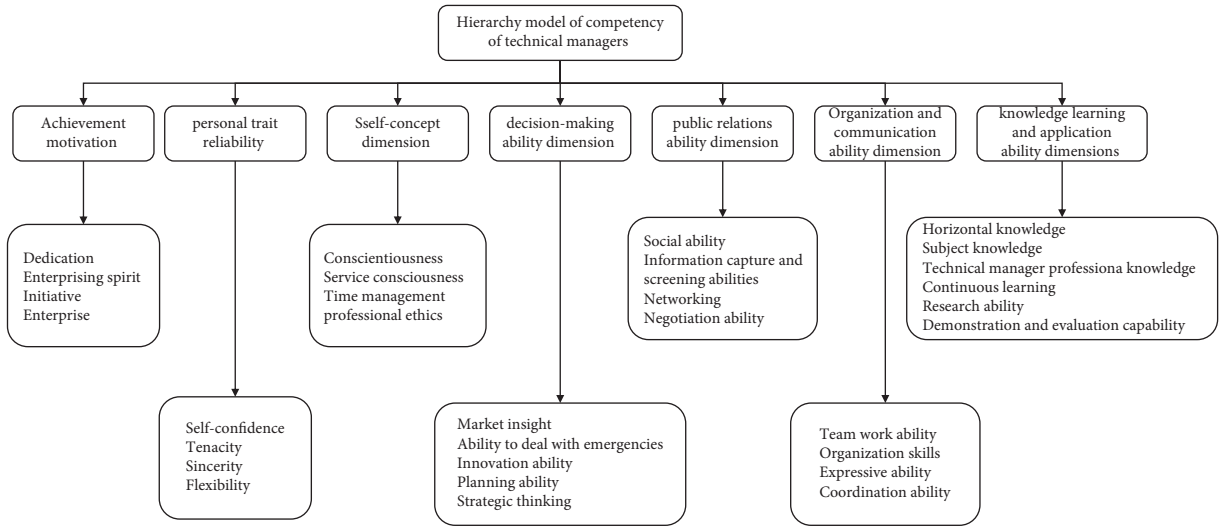

Figure 1: Hierarchy structure of competency of technical managers using AHP.

(3) Construction of Competency Model for Technical Managers. Through the above analysis, the technical manager competency model is finally obtained which includes 7 dimensions and 31 competency characteristics as shown in Table 13.

3. Application of Competency Model of Technical Managers

The first is to evaluate the model and then to determine the differences in competency requirements to solve the problem of unreasonable personal competency structure. Then use the model to evaluate the competency of a technical manager and show the practical application of the model [3].

3.1. Construction of Evaluation Index System. According to the results of the previous research, the seven dimensions of the technical manager competency model are taken as the primary indicators and the competency items of each dimension are taken as the secondary indicators to form the evaluation index system of the technical manager competency model.

3.2. Steps of Implementation Evaluation

3.2.1. Analytic Hierarchy Process (AHP). AHP combines qualitative analysis such as the experience judgment of experts and scholars with mathematical methods of quantitative calculation which not only highlights the advantages of stratification but also has both logic and rationality [3–6]. The main steps are as follows:

(1) Establish Hierarchical Model. Construct the hierarchical structure model of technical manager competency according to the evaluation index system as shown in Figure 1.

(2) Construct the Importance Judgment Matrix of Pairwise Comparison. The judgment matrix indicates starting from the second layer of the hierarchical structure model for the factors of the same layer subordinate to each factor of the upper layer. The paired comparison matrix is constructed by the paired comparison method and 1~9 scale method to the lowest layer. The structural form of the judgment matrix is shown in Table 14.

B_{ij} represents the quantitative judgment of the relative importance of B to B. Generally, the value of b_{ij} can take 1, 2,. . .,9 and their reciprocal as shown in Table 15.

Table 14: Structure of judgment matrix.

B	B	B	...	B
B	b	b	...	b
B	B	b	...	b
...	...	...	...	...
B	b	b		b

Table 15: Meaning of scale 1~9.

Importance level	B assignment
B is as important as B	1
B is slightly more important than B	3
B is more important than B	5
B is obviously more important than B	7
B is absolutely more important than B	9
B is more important than B between the above two levels	2,4,6,8
The importance of B over B is the reciprocal of the importance of B and B	1,1/2,. . .,1/9

(3) Consistency Test. The consistency index, random consistency index, and consistency ratio are used for consistency test. The calculation formula of consistency index is given in the following formula:

$$CI = \frac{(\lambda \max - n)}{(n-1)}, \tag{2}$$

where CI is the maximum eigenvalue of the judgment matrix.

For the average random consistency index, for the judgment matrix of order 1~12, the values are shown in Table 16.

By comparing the importance of seven dimensions, the first judgment matrix is constructed as shown in Table 17. The maximum eigenvalue and eigenvector values are calculated by using the numerical calculation software MATLAB. Table 17 shows judgment matrix of primary indicators.

The specific calculation steps are as follows:

(1) Steps for calculating eigenvalue and index weight:

$$\widetilde{w}_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}}, \tag{3}$$

$$\overrightarrow{B}\overrightarrow{w_{ij}} = \sum_{j=1}^{n} \widetilde{w}_{ij}, \tag{4}$$

$$\widetilde{w} = \left(\widetilde{w_1}, \widetilde{w_2}, \ldots, \widetilde{w_n}\right)^T. \tag{5}$$

$$W = [0.0810.0650.1280.1790.1900.1830.175]. \tag{6}$$

Step 1: Normalize each column vector of judgment matrix B as given below:

$\widetilde{w}_{ij}$ indicates the index weight.

Step 2: Add the normalized vectors of each row as shown in

Step 3: Normalize the vector to obtain the weight as shown in

By calculating weight matrices, W is calculated as shown in equation (6): eigenvalue : $\lambda_{\max} = 7.739$

(2) Calculate consistency index CI as shown in

$$\begin{aligned} CI &= \frac{\lambda_{\max} - n}{n-1} \\ &= \frac{7.739 - 7}{7-1} \\ &= 0.123. \end{aligned} \tag{7}$$

(3) Calculate consistency ratio as shown in equation (8):

Since n is 7, according to the above table, RI = 1.32,

$$\begin{aligned} CR &= \frac{CI}{RI} \\ &= \frac{0.123}{1.32} \\ &= 0.093. \end{aligned} \tag{8}$$

Similarly, the consistency test method of the secondary indicator judgment matrix of other dimensions is the same as that of the primary indicator, and the test results are as follows.

The weight of four secondary indicators of achievement motivation dimension = (0.338, 0.270, 0.237, 0.154), = 4.215, = 0.072, = 0.90, = 0.080 < 0.1.

The weight of four secondary indicators of personal trait dimension = (0.231, 0.148, 0.426, 0.195), = 4.046, = 0.015, = 0.90, = 0.017 < 0.1.

The weight of four secondary indicators of self-concept dimension = (0.283, 0.183, 0.163, 0.371), = 4.118, = 0.039, = 0.90, = 0.044 < 0.1.

The weight of five secondary indicators in the dimension of decision-making ability = (0.343, 0.122, 0.169, 0.124, 0.242), = 5.325, = 0.081, = 1.12, = 0.073 < 0.1.

The weights of four secondary indicators of public relation capability dimension = (0.146, 0.277, 0.373, 0.205), = 4.207, = 0.069, = 0.90, = 0.077 < 0.1.

The weight of four secondary indicators of the dimension of organizational communication ability = (0.239, 0.395, 0.198, 0.168), = 4.061, = 0.020, = 0.90, = 0.022 < 0.1.

The weights of six secondary indicators of knowledge learning and application dimension = (0.209, 0.110, 0.254, 0.196, 0.081, 0.149), = 7.739, = 0.123, = 1.24, = 0.093 < 0.1.

3.2.2. Fuzzy Comprehensive Evaluation Method. Select a technical manager a as the object of expert evaluation, and then use the fuzzy comprehensive evaluation method to evaluate his competency. The specific steps are as follows:

Table 16: Average random consistency index.

dimension	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53

Table 17: Judgment matrix of primary indicators.

B	B	B	B	B	B	B	B	Weight
Achievement motivation B	1	1	1/2	1/3	1	1/2	1/2	0.081
Personal characteristics B	1	1	1/3	1/3	1/2	1/2	1/2	0.065
Self-concept B	2	3	1	1	1/3	1	1/2	0.128
Decision-making ability B	3	3	3	1	1	1/3	2	0.179
Public relation capability B	1	2	3	1	1	2	1	0.190
Organizational and communication skills B	3	3	1	1/2	1/2	1	1/2	0.183
Knowledge learning and application ability B	2	2	2	1/2	1	2	1	0.175

Table 18: Evaluation of "achievement motivation" dimension of technical manager A.

Primary index	Secondary index	Evaluation grade				
		Excellent	Good	Commonly	Poor	Very bad
Achievement motivation	Enterprise	12	4	4	0	0
	Initiative	13	4	2	1	0
	Enterprising spirit	9	4	5	1	1
	Dedication	12	5	3	0	0

(1) Determining the fuzzy comprehensive evaluation factor (FCEF) set of technical manager competency == {achievement motivation, personal characteristics, self-concept, decision-making ability, public relation ability, organizational communication ability, knowledge learning and application ability} == {dedication, initiative, enterprising spirit and dedication} == {confidence, tenacity, integrity, flexibility} == {sense of responsibility, sense of service, time management, professional ethics} == {market insight; ability to deal with emergencies; innovation ability and planning ability; strategic thinking} == {social skills, information capture and screening skills, networking, negotiation skills} == {team work ability, organization ability, expression ability, coordination ability} == {horizontal knowledge, discipline knowledge, professional knowledge of technical managers, continuous learning, research ability, demonstration and evaluation ability}.

(2) Establish a comment set for comprehensive evaluation == {excellent, good, average, poor, very poor}.
V Indicates the evaluation level.

(3) Determine the weight of each evaluation index and construct a single factor fuzzy evaluation matrix.

The weight of each evaluation index has been obtained by using the AHP method. Here, only the single factor fuzzy evaluation matrix needs to be determined. 20 experts are invited to evaluate the secondary indicators of 7 dimensions of the competency of technical manager "A." The evaluation of experts on the "achievement motivation" dimension of technical manager "A" is shown in Table 18.

The distribution of the expert group evaluation on five levels constitutes a single factor evaluation matrix. When evaluating the "dedication" of technical manager a, 12 experts think that a is excellent, 4 think it is good, and 4 think it is average. Therefore, the fuzzy evaluation vector of the index of "dedication" = (0.6, 0.2, 0.2, 0, 0, 0). Using the same evaluation method, the fuzzy evaluation vectors of initiative, enterprising spirit, and dedication are obtained as follows: = (0.65, 0.2, 0.1, 0.05, 0) = (0.6, 0.25, 0.15, 0, 0) = (0.55, 0.25, 0.15, 0.05, 0).

The single factor fuzzy evaluation matrix of "achievement motivation" of technical manager "A" is as follows as shown in Matrix (9):

Achievement motivation:

$$= \begin{bmatrix} 0.6 & 0.2 & 0.2 & 0 & 0 \\ 0.65 & 0.2 & 0.1 & 0.05 & 0 \\ 0.6 & 0.25 & 0.15 & 0 & 0 \\ 0.55 & 0.25 & 0.15 & 0.05 & 0 \end{bmatrix}. \quad (9)$$

Similarly, it can be concluded that personal characteristics can be obtained by

$$= \begin{bmatrix} 0.5 & 0.3 & 0.1 & 0.1 & 0 \\ 0.4 & 0.3 & 0.2 & 0.05 & 0.05 \\ 0.5 & 0.3 & 0.15 & 0.05 & 0 \\ 0.4 & 0.2 & 0.15 & 0.15 & 0.1 \end{bmatrix}. \quad (10)$$

Self-concept is given by

$$= \begin{bmatrix} 0.5 & 0.25 & 0.25 & 0 & 0 \\ 0.5 & 0.2 & 0.2 & 0.1 & 0 \\ 0.45 & 0.25 & 0.15 & 0.1 & 0.05 \\ 0.55 & 0.25 & 0.2 & 0 & 0 \end{bmatrix}. \quad (11)$$

Decision-making ability is given by

$$= \begin{bmatrix} 0.45 & 0.3 & 0.2 & 0.05 & 0 \\ 0.4 & 0.25 & 0.2 & 0.1 & 0.05 \\ 0.4 & 0.3 & 0.2 & 0.05 & 0.05 \\ 0.45 & 0.25 & 0.25 & 0.05 & 0 \\ 0.35 & 0.2 & 0.25 & 0.1 & 0.1 \end{bmatrix}. \quad (12)$$

Public relation ability is given by

$$= \begin{bmatrix} 0.5 & 0.3 & 0.15 & 0.05 & 0 \\ 0.45 & 0.35 & 0.1 & 0.05 & 0.05 \\ 0.5 & 0.25 & 0.1 & 0.1 & 0.05 \\ 0.4 & 0.3 & 0.2 & 0.1 & 0 \end{bmatrix}. \quad (13)$$

Organizational and communication skills are given by

$$= \begin{bmatrix} 0.55 & 0.2 & 0.2 & 0.05 & 0 \\ 0.45 & 0.2 & 0.15 & 0.15 & 0.05 \\ 0.5 & 0.25 & 0.1 & 0.1 & 0.05 \\ 0.5 & 0.15 & 0.15 & 0.1 & 0.1 \end{bmatrix}. \quad (14)$$

Knowledge learning and application are given by

$$= \begin{bmatrix} 0.5 & 0.35 & 0.1 & 0.05 & 0 \\ 0.5 & 0.25 & 0.2 & 0.05 & 0 \\ 0.6 & 0.3 & 0.1 & 0 & 0 \\ 0.5 & 0.25 & 0.2 & 0.05 & 0 \\ 0.55 & 0.2 & 0.15 & 0.05 & 0.05 \\ 0.5 & 0.2 & 0.15 & 0.1 & 0.05 \end{bmatrix}. \quad (15)$$

(4) Carry Out Fuzzy Comprehensive Evaluation. Since there are many factors involved in the competency evaluation of technical managers, the evaluation results should be reasonable and should be able to comprehensively reflect the information of each single factor. The weighted average fuzzy synthesis algorithm is adopted to carry out the fuzzy comprehensive evaluation.

Table 19: Total evaluation of technical manager "*A*."

Evaluation grade	Excellent	Good	Average	Poor	Very poor
Percentage (%)	48.9	25.5	16.4	0.66	0.26

First-level comprehensive evaluation is given by

$$B_1 = W_1 \cdot U_1 \begin{bmatrix} 0.338 \\ 0.27 \\ 0.237 \\ 0.15 \end{bmatrix}' \cdot \begin{bmatrix} 0.6 & 0.2 & 0.2 & 0 & 0 \\ 0.65 & 0.2 & 0.1 & 0.05 & 0 \\ 0.6 & 0.25 & 0.15 & 0 & 0 \\ 0.55 & 0.25 & 0.15 & 0.05 & 0 \end{bmatrix} \quad (16)$$

$$= [\, 0.605 \;\; 0.219 \;\; 0.153 \;\; 0.021 \;\; 0.000 \,].$$

Similarly, the conclusion is obtained by

$$\begin{aligned} B_2 &= [\, 0.466 \;\; 0.281 \;\; 0.146 \;\; 0.081 \;\; 0.027 \,], \\ B_3 &= [\, 0.510 \;\; 0.241 \;\; 0.206 \;\; 0.035 \;\; 0.008 \,], \\ B_4 &= [\, 0.411 \;\; 0.264 \;\; 0.218 \;\; 0.068 \;\; 0.039 \,], \\ B_5 &= [\, 0.466 \;\; 0.296 \;\; 0.128 \;\; 0.079 \;\; 0.033 \,], \\ B_6 &= [\, 0.492 \;\; 0.202 \;\; 0.152 \;\; 0.108 \;\; 0.046 \,], \\ B_7 &= [\, 0.529 \;\; 0.272 \;\; 0.142 \;\; 0.045 \;\; 0.012 \,]. \end{aligned} \quad (17)$$

The above evaluation vectors form a comprehensive fuzzy evaluation matrix as given by Matrix (18) to obtain the secondary comprehensive evaluation of technical manager *A*:

$$B = W \cdot U$$

$$= \begin{bmatrix} 0.081 \\ 0.065 \\ 0.128 \\ 0.179 \\ 0.190 \\ 0.183 \\ 0.175 \end{bmatrix}' \cdot \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \end{bmatrix} \quad (18)$$

$$= [0.489 \;\; 0.255 \;\; 0.164 \;\; 0.066 \;\; 0.026].$$

(5) Analysis and Processing of Evaluation Results. The evaluation results show that in the evaluation of the comprehensive competence of technical manager "a," 48.9% of the experts think that the comprehensive quality of a is "excellent," 25.5% of the experts think that its comprehensive quality is "good," 16.4% of the experts think that its comprehensive

quality is "average," and 0.66% of the experts think that its comprehensive quality is "poor." The total evaluation of experts on technical manager "A" is shown in Table 19.

The above fuzzy comprehensive evaluation result is still a fuzzy vector, so it is difficult to determine the level of comprehensive evaluation. Therefore, it is necessary to make the vector accurate. Firstly, give corresponding scores [100 80 60 40 20] to the comment set {excellent, good, average, poor, and very poor} of the comprehensive evaluation and then calculate the comprehensive quality evaluation score of technical manager A as shown in

$$K = B \cdot \begin{bmatrix} 100 \\ 80 \\ 60 \\ 40 \\ 20 \end{bmatrix}^{T} = 82.30. \tag{19}$$

The results show that the comprehensive quality evaluation is close to the "good" level.

3.3. Discussion

(1) The competency model of technical managers constructed in this study covers 7 dimensions and 31 secondary competency indicators. At the same time, the judgment results of the importance of competency show that "public relation ability," "decision-making ability," and "organizational communication ability" are the most important competency dimensions of technical managers. The relevant departments can focus on three important dimensions to carry out targeted professional qualification certification and related training.

(2) The application research results of the competency model of technical managers show that the model is suitable for the effective evaluation of the competency of technical managers which will provide effective methods and ideas for the evaluation of the competency and performance of technical managers.

4. Conclusion

With the growing demands of development of the industry globally, the competency evaluation model for technical managers should be designed using multi-objective or multi-criteria decision analysis. The model should be continuously adjusted and improved, the design of indicators should be close to practice rather than theoretical concepts, and the methods of evaluation should be dynamic to adapt the changes with the time. Quality is a dynamic development process such as decision-making ability, public relation ability, organizational communication ability, and knowledge learning, and application ability will continue to improve with the growth of technical managers. Therefore, the evaluation model based on multiple criteria is designed and developed in this paper for evaluating the competency of technical managers. In order to ensure the accuracy and objectivity of the samples, questionnaires are used and the data are collected from Beijing, Shanghai, Chengdu, Nanjing, or developed cities in the eastern, central, and western regions. Then, statistical tests are performed to consider the factors that assist in judging the competency of technical managers. Then, multi-criteria techniques are applied such as AHP and fuzzy evaluation scheme (FCEF) and promising quantitative results are obtained as explained in the result section. In the future, more parameters will be studied and more multi-criteria methods will be applied to judge the competency level of technical managers based on multiple factors.

Data Availability

The data is available on request.

Conflicts of Interest

The authors have none to declare for conflicts of interest with respect to this article.

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References

[1] L. Tang and T. Zhang, "Study on the dynamic mechanism of technology transfer institutions in China," in *Proceedings of the 2021 International Conference on Diversified Education and Social Development (DESD 2021)*, pp. 244–247, Guiyang, China, June 2021.

[2] M. Kaur and S Kadam, "Discovery of resources over Cloud using MADM approaches," *International Journal for Engineering Modelling*, vol. 32, pp. 83–92, 2019.

[3] B. Mareschal, M. Kaur, V. Kharat, and S. Sakhare, "Convergence of smart technologies for digital transformation," *Tehnički Glasnik - Technical Journal*, vol. 15, p. 1, 2021.

[4] M. Kaur and S. S. Kadam, "Discovery of resources using MADM approaches for parallel and distributed computing," *Engg Sc. and Tech., an Int. J.*vol. 20, no. 3, pp. 1013–1024, 2017.

[5] M. Kaur, S. Kadam, and N. Hannoon, "Multi-level parallel scheduling of dependent-tasks using graph-partitioning and hybrid approaches over edge-cloud," *Soft Computing*, vol. 26, 2022.

[6] A. Jadhav, M. Kaur, and F. Akter, "Evolution of software development effort and cost estimation techniques: five decades study using automated text mining approach," *Mathematical Problems in Engineering*, vol. 2022, Article ID 5782587, 2022.

[7] M. Kaur, S. R. Sakhare, K. Wanjale, and F. Akter, "Early stroke prediction methods for prevention of strokes," *Behavioural Neurology, Hindawi*, vol. 2022, Article ID 7725597, 2022.

[8] T. Mandicak, P. Mesaros, M. Spisakova, and A. Kanalikova, "The knowledge competencies and digital competencies of project managers in life cycle cost management," in *Proceedings of the 2020 18th International Conference on Emerging eLearning Technologies and Applications (ICETA)*, pp. 438–443, Košice, Slovenia, November 2020.

[9] D. C. McClelland, "Testing for competence rather than for "intelligence"," *American Psychologist*, vol. 28, 1973.

[10] L. Jones and R. Moore, "Appropriating Competence: the competency movement, the New Right and the "culture change" project," *British Journal of Education and work*, vol. 8, no. 2, pp. 78–92, 1995.

[11] Y. Fajar Sitohang, "Competency evaluation of project manager performance in network construction projects," in *Proceedings of the 2020 Fifth International Conference on Informatics and Computing (ICIC)*, pp. 1–8, Gorontalo, Indonesia, November 2020.

[12] R. Dewi, W. Verina, and S. L. Rahayu, "Application of AHP Method Based on Competence for Determining the Best Graduate Students," in *Proceedings of the 2018 6th Int. Confe on Cyber and IT Service Mgmt (CITSM)*, pp. 1–5, Parapat, Indonesia, August 2018.

[13] T. Virtanen, "Changing competences of public managers: tensions in commitment," *Int. J.of Public Sector Mang.*vol. 13, no. 4, pp. 333–341, 2000.

[14] S. Ait Bahom, L. Sefiani, and N. Sefiani, "Identification of quality manager's competencies by the AHP method," in *Proceedings of the 2018 International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, pp. 133–139, Tangier, Morocco, April 2018.

[15] L. L. Luisito and M. P. Gary, "Competency-based mapping tool in personnel management system using analytical hierarchy process," in *Proceedings of the 2021 The 4th Int. Conf. on Machine Lear. and Machine Int.(MLMI'21)*, pp. 57–64, ACM, NY, USA, September 2021.

[16] V. Dulewicz and P. Herbert, "Predicting advancement to senior management from competencies and personality data: a seven-year follow-up study," *British Journal of Management*, vol. 10, no. 1, pp. 13–22, 1999.

[17] K. Zheng, "Analysis and research on professional quality and ability improvement for technology brokers," *Jiangsu Science & Tech. Info.*vol. 11, p. 41, 2019.

[18] L. Alencar and A. Almeida, "Supplier selection based on the PROMETHEE VI multicriteria method," in *Evolutionary Multi-Criterion Optimization. EMO 2011 Lecture Notes in Computer Science*vol. 6576, Berlin, Heidelberg, Springer, 2011.

[19] T. Wang and Y. Chen, "Applying fuzzy PROMETHEE method for evaluating IS outsourcing suppliers," in *Proceedings of the 2008 Fifth International Conference on Fuzzy Systems and Knowledge Discovery*, pp. 361–365, Jinan, China, October 2008.

[20] W.-C. Morais, A. T. de Almeida, L. H. Alencar, T. R. N. Clemente, and C. Z. B. Cavalcanti, "PROMETHEE-ROC model for assessing the readiness of technology for generating energy," *Mathematical Problems in Engineering*, vol. 2015, Article ID 530615, 11 pages, 2015.