A New Type of Enterprise Knowledge Management Performance Measurement Index System and Triangular Fuzzy Measurement Model

Zhi Dong

1Hebei University

2Graduate School of Chinese Academy of Social Sciences

E-Mail: youyayishu@163.com

Abstract: To promote the knowledge management of enterprises more effectively and enhance the market competitiveness of enterprises, this paper analyzes the enterprise knowledge management performance measurement index system and the measurement model in response to the problems existing in the knowledge management performance analysis process. This paper first discusses the principles needed to be followed in terms of the index selection in the process of enterprise knowledge management performance measurement and selects the measurement index of enterprise knowledge management performance under the guidance of index selection principles. Then, this paper establishes the enterprise knowledge management performance measurement index system with hierarchical structure on this basis. Finally, considering the multiform fuzzy information existing in the process of enterprise knowledge management performance measurement and to achieve the effective measurement of enterprise knowledge management performance, this paper establishes a type of knowledge management performance measurement model based on triangular fuzzy number, which realizes the measurement and analysis of the integrity and comprehensiveness of enterprise knowledge management performance.

Key words: knowledge management; performance evaluation; index system; enterprise; triangular fuzzy number; TOPSIS model

1. INTRODUCTION

With the advent of economy era, the development of scientific and technological enterprises has transformed from traditional management mode of manpower and material resources into the management mode of enterprise knowledge. The enterprise knowledge management has gradually become the mainstream model in modern enterprise management and plays an important role in promoting the sustainable development and maintaining the market competitiveness of enterprises (Wang et al., 2010; Zhang et al., 2015; Zhao, 2009). However, how to guarantee the effectiveness of performance analysis in the process of knowledge management is an important issue needed to be addressed, which has also attracted attention and research of many scholars (Yan and Li, 2001; Liao and Xiong, 2011). In terms of the evaluation method of knowledge management performance, many methods based on grey system and fuzzy system can be applied (Zhang and Ge, 2009; Zhou et al., 2009; Lai et al., 2009). In terms of the knowledge management performance model, many models based on Balanced Score Card (BSC), neural network, evidence reasoning and DEA can be applied (Zhang 2011; Duan et al., 2012; Li and Zhou, 2012; Ding, 2006). Besides, many scholars also analyze relevant factors and impact in the analysis of knowledge management performance measurement index system and knowledge management performance analysis (Zhang and Liu, 2007; Jin, 2014; Liu and Shen, 2015; Xie et al., 2014). These research achievements play a positive
role in achieving effective knowledge management performance analysis and promoting knowledge management level. With the continuous social development in economy era, more and more problems have emerged in knowledge management. To satisfy the urgent demand of knowledge management by modern social enterprises, this paper discusses a new type of enterprise knowledge management performance measurement index system and the triangular fuzzy measurement model in expectation of promoting the benign development of enterprises.

2. SELECTION PRINCIPLES OF ENTERPRISE KNOWLEDGE MANAGEMENT PERFORMANCE MEASUREMENT INDEX

Many factors need to be considered in the process of enterprise knowledge management performance analysis, including enterprise ’ s internal and external information, explicit information and implicit information and static information and dynamic information. Therefore, corresponding selection principles need to be followed to achieve the scientific and reasonable selection of enterprise management performance measurement index, as is shown in Table 1.

Table 1 Selection principles of enterprise management performance measurement index

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Type</th>
<th>Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Systematic principle</td>
<td>The selection of enterprise knowledge management performance measurement index must be systematic and can reflect the essential problems of performance analysis from an overall perspective.</td>
</tr>
<tr>
<td>2</td>
<td>Hierarchical principle</td>
<td>Subordinate relation often exists in the measurement index and the measurement index of different hierarchies exerts different impact on the results of enterprise knowledge management performance analysis.</td>
</tr>
<tr>
<td>3</td>
<td>Comparative principle</td>
<td>No matter accurate indexes or fuzzy indexes must be able to conduct effective quantification to reflect the actual result of performance analysis.</td>
</tr>
<tr>
<td>4</td>
<td>Moderate refinement principle</td>
<td>In hierarchical framework, the classification of indexes cannot be too rough or elaborate. Rough classification cannot fully represent the essential problems of indexes while elaborate classification often leads to the information overlap among indexes, influencing the reliability of performance analysis results.</td>
</tr>
<tr>
<td>5</td>
<td>Representative principle</td>
<td>If the number of indexes is large, it is not appropriate to select them all. Important measurement indexes should be selected as representative indexes while unimportant measurement indexes can be neglected.</td>
</tr>
<tr>
<td>6</td>
<td>Dynamic principle</td>
<td>The enterprise knowledge management performance measurement index should reflect the dynamic and sociality of the sustainable development of enterprises, but not limited to the current situation and internal condition of enterprises.</td>
</tr>
<tr>
<td>7</td>
<td>Scientific principle</td>
<td>The enterprise knowledge management performance measurement index should be selected from scientific, objective, reasonable, practical and realistic perspective to conform to the actual situation of enterprise knowledge management.</td>
</tr>
<tr>
<td>8</td>
<td>Comprehensive principle</td>
<td>The enterprise knowledge management involves content in various aspects and exerts comprehensive impact on enterprise knowledge management ability. Therefore, the enterprise knowledge management performance measurement index should reflect each level of knowledge management.</td>
</tr>
</tbody>
</table>
3. ESTABLISHMENT OF ENTERPRISE KNOWLEDGE MANAGEMENT PERFORMANCE MEASUREMENT INDEX SYSTEM

The writer thinks that the enterprise knowledge management performance measurement index system can be established from the perspective of input capacity and capital, organization and management, embodiment of the management, planning and construction of the platform and implementation effect under the guidance of above-mentioned selection principles, as is show in Table 2.

**Table 2** Enterprise knowledge management performance measurement index system

<table>
<thead>
<tr>
<th>System hierarchy</th>
<th>First grade index</th>
<th>Secondary index</th>
<th>Concrete implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input capacity and capital</td>
<td>Human capital factor</td>
<td></td>
<td>The input and preparation of various aspects conducted by enterprises in the process of knowledge management and the basic conditions and potential ability in each aspect.</td>
</tr>
<tr>
<td></td>
<td>Technological capital factor</td>
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<td></td>
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<tr>
<td></td>
<td>Material capital factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Financial capital factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technological capital factor</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Market capital factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Financial capital factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization and management</td>
<td>Flattening degree of enterprise structure</td>
<td></td>
<td>Relevant factors concerning enterprise organizational structure that exert direct influence on the knowledge management.</td>
</tr>
<tr>
<td></td>
<td>Organization establishment of enterprise knowledge management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Team building of enterprise knowledge management</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human resource management</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Service and safeguard mechanism</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Planning and setting of mechanism</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Soundness of operation mechanism</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enterprise cultural environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learning and training conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embodiment of the management</td>
<td>Knowledge acquisition factor</td>
<td></td>
<td>In the process of knowledge management implementation, different knowledge management links and activities exert different impact on management performance and these course factors call for comprehensive consideration.</td>
</tr>
<tr>
<td></td>
<td>Knowledge modeling factor</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Knowledge storage factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge sharing and integration factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge transformation and utilization factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge communication and transferring factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knowledge integration factor</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Knowledge innovation factor</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Knowledge stock factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning and construction</td>
<td>Knowledge management platform and system</td>
<td></td>
<td>The software and hardware platform and the support by</td>
</tr>
</tbody>
</table>
After the implementation of knowledge management, enterprises obtain relevant factors concerning the competitiveness improvement.

### 4. TRIANGULAR FUZZY MEASUREMENT MODEL OF ENTERPRISE KNOWLEDGE MANAGEMENT PERFORMANCE MEASUREMENT ANALYSIS

#### 4.1 Basic model of triangular fuzzy number

If fuzzy number $E$ can be determined by $(e^{min}, e^{mid}, e^{max})$ and $e^{min} \leq e^{mid} \leq e^{max}$, while $e^{min}$ is the lower limit of fuzzy number $E$ and $e^{max}$ is the upper limit of fuzzy number $E$, $e^{mid}$ is the most likely spot of fuzzy number $E$ and the fuzzy membership function of fuzzy number $\theta_E(x)$ can be expresses as:

$$
\theta_E(x) = \begin{cases} 
\frac{x - e^{min}}{e^{mid} - e^{min}}, & e^{min} \leq x \leq e^{mid} \\
0, & x \notin [e^{min}, e^{max}] \\
1, & x = e^{mid} \\
\frac{e^{max} - x}{e^{max} - e^{mid}}, & e^{mid} < x \leq e^{max} 
\end{cases}
$$

(1)
Then we call $E=(e_{min}, e_{mid}, e_{max})$ triangular fuzzy number (Hadi, 2009; Shu-Ping, 2013; Pietro et al., 2014; Li and Hong, 2016). In this equation, $|e_{max}-e_{min}|$ represents the fuzzy extent of triangular fuzzy number $E$. The greater the value of $|e_{max}-e_{min}|$, the higher the extent of triangular fuzzy number $E$. On the contrary, the smaller the value of $|e_{max}-e_{min}|$, the lower the extent of triangular fuzzy number $E$. Particularly, when $e_{min}=e_{mid}=e_{max}$, the value of triangular fuzzy number $E$ is accurate, without the characteristics of fuzziness.

If triangular fuzzy number $E_a=(e_{min}^a, e_{mid}^a, e_{max}^a)$ and triangular fuzzy number $E_b=(e_{min}^b, e_{mid}^b, e_{max}^b)$, then these two equations satisfy the following operational form.

Sum/difference operation:

$$E_a \pm E_b = (e_{min}^a \pm e_{min}^b, e_{mid}^a \pm e_{mid}^b, e_{max}^a \pm e_{max}^b)$$

(2)

Multiplication operation:

$$E_a \odot E_b = (e_{min}^a \cdot e_{min}^b, e_{mid}^a \cdot e_{mid}^b, e_{max}^a \cdot e_{max}^b)$$

(3)

Specially, if one of fuzzy numbers change into real number $K$, the above equation will transform into scalar multiplication operation.

$$K \odot E_a = (K \cdot e_{min}^a, K \cdot e_{mid}^a, K \cdot e_{max}^a)$$

(4)

Division operation

$$E_a \div E_b = (e_{min}^a \div e_{max}^b, e_{mid}^a \div e_{mid}^b, e_{max}^a \div e_{max}^b)$$

(5)

Specially, if triangular fuzzy number $E_a=(e_{min}^a, e_{mid}^a, e_{max}^a)$ and triangular fuzzy number $E_b=(e_{min}^b, e_{mid}^b, e_{max}^b)$, then the fuzzy distance between the two is:

$$d(E_a, E_b) = \frac{1}{3} \left( (e_{min}^a - e_{min}^b)^2 + (e_{mid}^a - e_{mid}^b)^2 + (e_{max}^a - e_{max}^b)^2 \right)$$

(6)

4.2 Construction of knowledge management performance measurement analysis scheme set

There are several schemes that can be applied in knowledge management performance measurement. To enable the analysis result to truly reflect the performance result, we need to conduct preliminary screening on the schemes applied in performance analysis. That is to say, only the schemes satisfying the mandatory constraint condition can make it to the optimization in the next round. The setting of mandatory constraint condition can be based on the actual situation and optimizing target of the objects. Assume that there are $m$ schemes satisfying the initial constraint condition and the $i$th scheme is recorded as $C_i$, and then the scheme set $C$ can be expressed as:

$$C = \{C_1, C_2, \ldots, C_i, \ldots, C_{m-1}, C_m\}$$

(7)
4.3 Construction of knowledge management performance measurement analysis index set

To achieve effective performance analysis of multiple schemes, specific, objective and scientific evaluation and optimization criteria must be established. That is to say, we need to formulate scheme performance measurement index. Assume that there are \( n \) indexes satisfying the requirement and the \( j \)th index is recorded as \( u_j \), and then the index set \( U \) can be expressed as:

\[
U = \{u_1, u_2, \ldots, u_j, \ldots, u_{n-1}, u_n\}
\]  

(8)

4.4 Construction of decision matrix

Through seeking expert opinions, comprehensive utilization of statistical analysis, questionnaire and expert grading, obtain the index data from scheme set \( C \) based on the established index set \( U \). Assume the value of index \( j \) in scheme \( I \) is \( E_{ij} = (e_{ij}^{\text{min}}, e_{ij}^{\text{mid}}, e_{ij}^{\text{max}}) \), and then the corresponding initial decision matrix \( E \) of scheme set \( C \) is:

\[
E = \left[ E_{ij} \right]_{mn} = \left[ (e_{ij}^{\text{min}}, e_{ij}^{\text{mid}}, e_{ij}^{\text{max}}) \right]_{mn}
\]

(9)

4.5 Standardization processing of matrix

There are two forms of measurement indexes, which are positive indexes and negative indexes and they often possess different dimensions. Therefore, standardization processing needs to be conducted for the unitary scale of all indexes.

If index \( j \) is positive index, the value \( v_{ij} \) of index \( j \) in scheme \( i \) after standardization processing is:

\[
v_{ij} = \left( v_{ij}^{\text{min}}, v_{ij}^{\text{mid}}, v_{ij}^{\text{max}} \right) = \left( e_{ij}^{\text{min}} / \max_{I \in C} e_{ij}^{\text{min}}, e_{ij}^{\text{mid}} / \max_{I \in C} e_{ij}^{\text{mid}}, e_{ij}^{\text{max}} / \max_{I \in C} e_{ij}^{\text{max}} \right)
\]

(10)

Specially, when \( e_{ij}^{\text{min}} = e_{ij}^{\text{mid}} = e_{ij}^{\text{max}} \), \( v_{ij} \) is the standardization result of accurate value, which is:

\[
v_{ij} = \frac{E_{ij}}{\max_{I \in C} E_{ij}}
\]

(11)

If index \( j \) is negative index, the value \( v_{ij} \) of index \( j \) in scheme \( i \) after standardization processing is:

\[
v_{ij} = \left( v_{ij}^{\text{min}}, v_{ij}^{\text{mid}}, v_{ij}^{\text{max}} \right) = \left( \min_{I \in C} e_{ij}^{\text{min}} / e_{ij}, \min_{I \in C} e_{ij}^{\text{mid}} / e_{ij}, \min_{I \in C} e_{ij}^{\text{max}} / e_{ij} \right)
\]

(12)

Specially, when \( e_{ij}^{\text{min}} = e_{ij}^{\text{mid}} = e_{ij}^{\text{max}} \), \( v_{ij} \) is the standardization result of accurate value, which is:

\[
v_{ij} = \frac{\min_{I \in C} E_{ij}}{E_{ij}}
\]

(13)

Then the corresponding decision matrix \( V \) of scheme set \( C \) is:
4.6 Ideal scheme and ideal scheme set

The positive ideal scheme \(H^+_j\) of measurement index \(j\) is:

\[
H^+_j = \left( h^+_{j,\text{min}}, h^+_{j,\text{mid}}, h^+_{j,\text{max}} \right) = \left( \max_{i \in \text{set}} v^+_{ij,\text{min}}, \max_{i \in \text{set}} v^+_{ij,\text{mid}}, \max_{i \in \text{set}} v^+_{ij,\text{max}} \right)
\]  

(15)

The negative ideal scheme \(H^-_j\) of measurement index \(j\) is:

\[
H^-_j = \left( h^-_{j,\text{min}}, h^-_{j,\text{mid}}, h^-_{j,\text{max}} \right) = \left( \min_{i \in \text{set}} v^-_{ij,\text{min}}, \min_{i \in \text{set}} v^-_{ij,\text{mid}}, \min_{i \in \text{set}} v^-_{ij,\text{max}} \right)
\]  

(16)

Then, we can obtain the positive ideal scheme set \(H^+\) of index set

\[
H^+ = \{H^+_1, H^+_2, \ldots, H^+_n\}
\]  

(17)

The negative ideal scheme set \(H^-\) of index set

\[
H^- = \{H^-_1, H^-_2, \ldots, H^-_n\}
\]  

(18)

4.7 Triangular fuzzy number distance of scheme optimization

Based on formula (6), the fuzzy distance \(\bar{d}(v_j, H^+_j)\) of index \(j\) between scheme \(i\) and positive ideal scheme \(H^+_j\) is:

\[
\bar{d}(v_j, H^+_j) = \frac{1}{\sqrt{3}} \left( (v^+_{ij,\text{min}} - h^+_{j,\text{min}})^2 + (v^+_{ij,\text{mid}} - h^+_{j,\text{mid}})^2 + (v^+_{ij,\text{max}} - h^+_{j,\text{max}})^2 \right)
\]  

(19)

The fuzzy distance \(\bar{d}(v_j, H^-_j)\) of index \(j\) between scheme \(i\) and native ideal scheme \(H^-_j\) is:

\[
\bar{d}(v_j, H^-_j) = \frac{1}{\sqrt{3}} \left( (v^-_{ij,\text{min}} - h^-_{j,\text{min}})^2 + (v^-_{ij,\text{mid}} - h^-_{j,\text{mid}})^2 + (v^-_{ij,\text{max}} - h^-_{j,\text{max}})^2 \right)
\]  

(20)

4.8 Weight of measurement index

The importance of different measurement indexes is different. That is to say, the contribution extent to performance analysis result is different. To better distinguish the results and improve the reliability and accuracy of the results, the weight of indexes needs to be generated. At present, various methods can be applied in the decision index weight generation, including AHP method, entropy method, fuzzy theory method and neural network method. AHP method is simple, direct, practical and reliable, and thus this paper applies AHP method for decision index weight generation. Assume that the weight of decision index \(j\) is \(w_j\), and the weight sequence \(W\) is

\[
W = \{w_1, w_2, \ldots, w_j, \ldots, w_n\}, \quad \sum_{j=1}^n w_j = 1
\]  

(21)
4.9 OPSIS model realization

After comprehensive consideration of the influence of measurement index weight, the fuzzy distance $\bar{D}(C_i, H^\Delta)$ between scheme $i$ and positive ideal scheme set $H^\Delta$ is:

$$\bar{D}(C_i, H^\Delta) = \sum_{j=1}^{n} (w_j \cdot d(v_j, H^\Delta))$$

(22)

The fuzzy distance $\bar{D}(C_i, H^\Delta)$ between scheme $i$ and negative ideal scheme set $H^\Delta$ is:

$$\bar{D}(C_i, H^\Delta) = \sum_{j=1}^{n} (w_j \cdot d(v_j, H^\Delta))$$

(23)

The comprehensive weighted correlation between scheme $i$ and ideal scheme set is:

$$\delta_i = \frac{\bar{D}(C_i, H^\Delta)}{\bar{D}(C_i, H^\Delta) + \bar{D}(C_i, H^\Delta)}$$

(24)

Then, based on optimization principles, we can obtain:

$$\delta_o = \max_{i \in S \cup G} (\delta_i) = \delta_i$$

(25)

We can know from above equation that scheme $k$ is the optimal scheme and receives the optimal performance measurement result.

5. CONCLUSION

The innovative parts of this part can mainly be seen in two aspects. The first is that this paper establishes a new type of enterprise knowledge management performance system based on the limitations in the knowledge management performance analysis index system, making it conform to the objective reality of knowledge management. The second is that this paper establishes a type of knowledge management performance measurement model based on triangular fuzzy number considering the fuzzy information existing in the process of enterprise knowledge management performance analysis. However, we still note that because of the diversity of influence factors, the extent of the refinement in the knowledge management performance analysis indexes needs to be further optimized to better reflect the essence of knowledge management, but the extent of the refinement must be determined by the objective conditions of enterprise development.

6. REFERENCE


