Performance Evaluation Method of SOEs Based On An Index Retrieval Technology And OPA

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Abstract. Performance evaluation plays an important role in promoting the high-quality development of state-owned enterprises (SOEs). A set of index retrieval technology is designed, using web crawler technology and word frequency technology, to build an alternative-index library. A performance evaluation method based on the alternative-index library and a five-force framework is proposed to construct a performance evaluation index system of SOEs, and using OPA as a weighting method. Then an example is proposed to illustrate the feasibility and validity of the method. It aims to extend the theory of enterprise performance, and to help promote the high-quality development of SOEs.

Keywords: state-owned enterprises; performance evaluation; high quality development; index retrieval technology; OPA

1 Introduction

The transition from a stage of rapid economic growth to a stage of high-quality development is a distinctive feature of Chinese economic in a new era. As an important pillar of the development of the national economy, SOEs play an important role in this process[1]. Performance evaluation plays an important role in guiding the operation and development of SOEs. However, the existing performance evaluation system in China has been unable to meet the needs of high-quality development. In view of this, our study proposes a set of system evaluation methods based on an index retrieval technology and Ordinal Priority Approach(OPA).

About the research on the performance evaluation, Du Shengli put forward the "trinity" evaluation standard and the principle of value management, emphasizing the comprehensive evaluation of economic, social and ecological benefits[2]. Chi Guohua designed an EVA

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management performance evaluation system adapted to the environment of Chinese enterprises[3].Wang Juan applied the Delphi method and the hierarchical analysis method to improve the enterprise performance evaluation[4]. Alexius and Ornberg believed that SOEs should pay more attention to social responsibility rather than economic benefits[5], Jong-seok sorted out the opinions of many scholars on the performance evaluation of SOEs, and pointed out that the problems restricting the effective performance evaluation of SOEs are mainly the lack of reasonable performance evaluation indexes[6]. In addition, some scholars also carried out some empirical researches, and built their own evaluation index systems, emphasizing the assessment of innovation, coordination, green, openness, sharing and other aspects[7-8].

The research on the performance evaluation of SOEs fails to keep pace with the Times; while the high-quality development of enterprises has not yet focused on the performance evaluation of SOEs. To make up the gap, on the basis of the existing research, this study designs an index retrieval technology and establishes a performance evaluation method of SOEs to meet the policy requirements and the practical needs of SOEs.

2 The establish of a performance evaluation system based on an index retrieval technology

This research puts forward an index retrieval technology to construct the performance evaluation index system of SOEs. The proposed method consists of some steps which have been outlined in the following. The flowchart representing the stages of the proposed method has been presented in Figure 1.

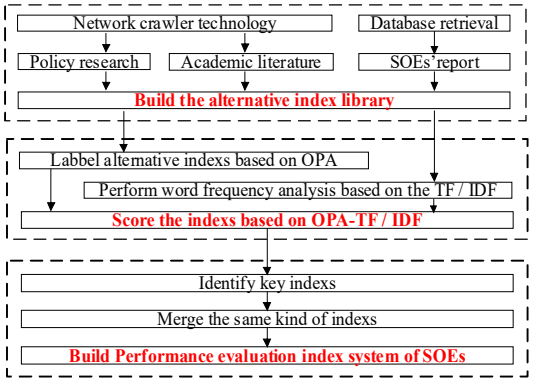

Figure 1. Flowchart of the index system establishment.

2.1 Building an alternative-index library

This research studies the specific key words of high-quality development evaluation of SOEs from three aspects: policy research, academic literature and SOE report. In terms of policy research, web crawler technology is used to extract texts related to high-quality development from official websites such as The State Council, perform word segmentation processing on them, extract keywords related to performance evaluation of SOEs, and form a word cloud map, as shown in Figure 2. In terms of academic literature, SCI/EI search was carried out.

CNKI and Wanfang Datbase searched with keywords such as high-quality development of SOEs and performance evaluation system. Academic literature with high correlation, recent publication time and high citation was selected to summarize and sort out alternative indexes. About reports of SOEs, representative SOEs are selected, the texts related to enterprise performance management are crawled from the official website by crawler technology, and key words related to the high-quality development of SOEs are sorted out by word segmentation technology. Based on the index retrieval of the above three parts, we construct an alternative-index library.

Figure 2. Word cloud diagram.

2.2 Score the index based on OPA-TF/IDF

First, OPA proposed by Amin(2020)[15] is applied to label the indexes. Criteria are publication time and index source. Alternatives are recent policy, past policy, recent report, past report, recent literature, past literature.An expert ranked the alternatives based on 3 principles: (1) Publication time>Index source;(2) near > far in time;(3) Policy > Report > Literature in index source. The result has been presented in Table 1.

Table 1. 1The importance of criteria by opa.

Source type	Recent	Past
Policy Research	0.27	0.16
SOEs' report	0.21	0.10
Academic literature	0.19	0.07

Second, this research uses word frequency statistics to determine the hot words by the frequency of the occurrence of certain key words. The main method for calculating the feature weight of word frequency is Term Frequence-Inverse Document Frequency(TF-IDF). If the TF of a certain keyword is higher in a text, but it appears less in other texts, that is, the larger the IDF, it is considered that this keyword has a better classification function. TF-IDF is the result of the multiplication of TF and IDF. The larger the value, the more important the keyword is to the text. We use Eq.(1)-Eq.(3) to calculate $TF_{i,j}$, IDF_i and $TF\text{-}IDF_{i,j}$.

$$TF_{i,j} = \frac{n_{ij}}{\sum_k n_{kj}} \quad \forall i, j \tag{1}$$

$$IDF_i = \log \frac{|D|}{1 + |j : t_i \in d_j|} \quad \forall i \tag{1}$$

$$TF - IDF_{i,j} = TF_{i,j} \times IDF_i \quad \forall i, j \tag{3}$$

Where $n_{i,j}$ is the frequency of keyword t_i appearing in d_j document; $TF_{i,j}$ is the frequency of keyword t_i appearing in document d_j; $|D|$ represents the total number of documents; $|j:t_i \in d_j|$ represents the number of documents containing keyword t_i. Based on the critical degree of index t_i to document d_j, $TF\text{-}IDF_{i,j}$, we use Eq. (4) to score the importance of index t_i.

$$B_i = \frac{\sum_j TF - IDF_{i,j}}{1 + \left| j : t_i \in d_j \right|} \quad \forall i \tag{4}$$

At last, we believe that the methods OPA and TF-IDF are equally important, that is, S_{OPA}=$S_{TF\text{-}IDF}$=0.5. The formula for calculating the final score L_i of index i in the alternative-index library is Eq. (5).

$$L_i = S_{OPA} \times A_i + S_{TF-IDF} \times B_i \quad \forall i \tag{5}$$

2.3 Build a performance evaluation system for SOEs

Innovation, competition, control, impact and risk resistance are the core driving forces for the high-quality development of SOEs[9]. They together constitute a five-force framework for the performance evaluation of SOEs, as shown in Figure 3.

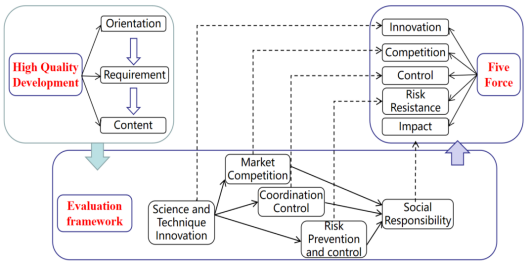

Figure 3. Five-force framework of performance evaluation of SOEs.

Based on the alternative-index library, 30 indexes with the highest L_i are selected according to the final score. Then, if many of them have similar connotations, they are grouped into the same index and named in a unified way, which ultimately constitutes the performance evaluation index system of SOEs under the background of high-quality development. The performance evaluation index system of SOEs is proposed as shown in Table 2.

Table 2. 2Performance evaluation index system of SOes.

Primary indexes	Secondary indexes	Explanatory variables	Index source
Market competition	Profit return (A1)	Rate of return on total assets	[10]
	Operating growth (A2)	Economic added value	
	Business capacity (A3)	Asset scale	
Science and technological innovation	Innovation investment (A4)	R&D investment intensity	[11]
	Innovation output (A5)	Innovation output	

Risk prevention and control	Asset operations (A6)	Total asset turnover	[12]
	Debt payingability (A7)	Asset-liability ratio	
Coordination control	Internal control (A8)	Internal administrative control	[13]
	External control (A9)	Industrial chain and intensive control level	
Social responsibility	National strategy implementation (A10)	Completion of major tasks	[14]
	Green and low carbon (A11)	Carbon emissions per unit of output	
	Sharing level (A12)	Capital and social sharing level	

3 Evaluating Procedure

OPA is considered the forefront MCDM technique. In contrast to methods like TOPSIS, VIKOR, and BWM, OPA employs ranking data as input, enabling the simultaneous computation of weights for experts, criteria and alternatives by solving a linear programming model[15,16]. This study utilizes OPA for calculating the weights of performance evaluation indexes in SOEs. Table 3 elaborates on the sets, indexes, variables, and parameters required for the computation of weights of SOE performance evaluation indexes.

Table 3. Sets, indexes, variables, and parameters for OPA.

Type	Notation	Definition
Index	i	Index of experts $(1,2,\ldots,p)$
	j	Index of subordinate indexes $(1,2,\ldots,m)$
Set	I	Set of experts $\forall i \in I$
	J	Set of subordinate indexes $\forall j \in J$
Variable	Z	Objective function: unrestricted in sigh
	W_{ij}^{r}	Weight of the subordinate indexes j based on the preference of the expert i
Parameter	r_i	Rank of the expert i
	r_{ij}	Rank of the subordinate indexes j under the expert i

Combined with the performance evaluation index system of SOEs, OPA consists of some procedure steps which have been outlined in the following.

Step 1: Identify the expert and give the ranking r_i of expert i according to the expert's professional ability.

Step 2: Expert i independently gives the ranking r_{ij} of the subordinate index j.

Step 3: All experts jointly give the score S_j of a certain SOE under the subordinate index j.

Step 4: Use the data in step 1 and Step 2 to build OPA model (6),which solved by MATLAB, finally get W_{ij}.

$$
\begin{aligned}
&\max Z \\
&s.t. \\
&Z \le r_i(r_{ij}(W_{ij}^{r_{ij}} - W_{ij}^{r_{ij}+1})) \quad \forall i \ and \ j \\
&Z \le r_i r_{ij} W_{ij}^{r_{ij}=m} \quad \forall i \ and \ r_{ij} = m \\
&\sum_{i=1}^{p}\sum_{j=1}^{m} W_{ij}^{r_{ij}} = 1 \\
&W_{ij}^{r_{ij}} \ge 0 \quad \forall i \ and \ j
\end{aligned}
\tag{6}
$$

Step 5: Calculate the weight of each subordinate index by Eq. (7).

$$
W_j = \sum_{i=1}^{p} W_{ij} \quad \forall j \tag{7}
$$

Step 6: Calculate the final score of the performance evaluation of a SOE by Eq. (8).

$$
S = \sum_{j=1}^{12} W_j \times S_j \tag{8}
$$

4 Case Analysis

This article uses data of enterprise A(after declassification) as the basic data for case analysis, and invites 12 experts in the related areas to conduct case analysis to verify the effectiveness of the proposed method. The experts are divided into three groups according to their authority in performance evaluation theory and practice, namely E1～E4, E5～E8, and E9～E12, and are ranked 1, 2 and 3 respectively, shown in Table 4.

Table 4. Priorities of Experts.

Expert	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Priority	1	1	1	1	2	2	2	2	3	3	3	3

The importance orders of each index given by the experts are shown in Table 5.

Table 5. The importance orders of each index.

Expert	Priority	Index	E1	E2	E3	E4	E5	E6
E1	1	A1	2	1	4	1	6	4
E2	1	A2	3	1	4	1	6	4
E3	1	A3	4	1	3	1	6	1
E4	1	A4	7	6	8	5	1	4
E5	2	A5	8	6	2	5	1	1
E6	2	A6	5	4	4	7	9	9
E7	2	A7	6	4	4	7	9	9
E8	2	A8	9	9	8	9	11	9

E9	3	A9	10	9	8	9	11	9
E10	3	A10	1	6	1	1	3	1
E11	3	A11	11	11	11	11	3	4
E12	3	A12	12	11	11	11	3	4
Expert	Prioriy	Index	E7	E8	E9	E10	E11	E12
E1	1	A1	3	3	6	1	5	9
E2	1	A2	3	4	6	1	5	4
E3	1	A3	3	5	6	1	5	3
E4	1	A4	3	6	4	4	1	5
E5	2	A5	3	7	4	4	1	2
E6	2	A6	3	8	9	6	5	4
E7	2	A7	3	9	9	6	5	5
E8	2	A8	10	10	11	8	11	6
E9	3	A9	10	11	11	8	12	7
E10	3	A10	1	2	1	10	1	1
E11	3	A11	1	1	1	10	1	8
E12	3	A12	10	12	1	10	10	10

The basic scores for each index given by the experts are shown in Table 6. The weight results of each index calculated according to the OPA method are shown in Figure 4.

Table 6. The basic scores for each index

Index	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
Score	88	90	96	91	87	96	98	99	80	96	90	88

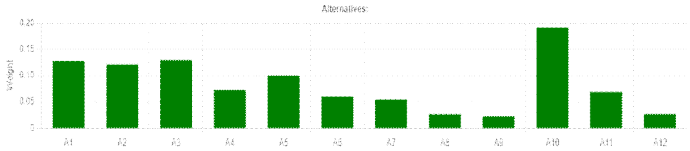

Figure 4. Weight results of each index.

According to the results, it was found that national strategy implementation (A10) has the highest weight, reaching 0.19, significantly higher than other indexes. This result is consistent with the actual situation, as in the evaluation of 12 experts, this index was ranked in the top three positions most of the time. Following closely behind are business capacity (A3), profit return (A1), and operating growth (A2), emphasizing the importance of a company's market competitiveness. Only when a company's economic foundation is solid can it have sufficient resources to innovate and make contributions to society. The weight of innovation output (A5) is also relatively high, reflecting the richness of a company's scientific and technological innovation achievements, which is complementary to the high priority given to innovation investment (A4) by the company. However, we noticed that the current level of attention on internal control (A8), external control (A9), and sharing level (A12) still needs to be improved.

Overall, the comprehensive score of the company's performance evaluation is 92.2, indicating excellent performance. Therefore, it is recommended that while maintaining market competitiveness, innovation, and risk control, companies should pay more attention to improving coordination control and social contribution.

5 Conclusions

High-quality development brings new demand to the performance evaluation of SOEs. Based on the index retrieval technology, this study designs the performance evaluation index system of SOEs, and then puts forward a performance evaluation procedure based on OPA. This method provides a systematic solution for the performance evaluation of SOEs from five dimensions: enterprise innovation ability, market competition, coordination and control, risk prevention and control, and social contribution. Through an example application, this method verifies its feasibility and effectiveness in the performance evaluation process of SOEs, hoping to provide an effective, scientific and objective theoretical support for the high-quality development of SOEs.

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