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Research Article

A TOPSIS-Based Model for Evaluating the Performance of the Intellectual Property Value Strategies of Science and Technology Enterprises

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Intellectual property comes with risks such as value evaluation and externalities. It is an intangible asset involving a large investment and a long return period; however, it plays an important role in enhancing the competitiveness of enterprises. Some companies see intellectual property as being a long-term development strategy, which makes evaluating the performance of corporate intellectual property particularly important. The TOPSIS method is widely used to evaluate the pros and cons, as well as the performance of various programs. It can make full use of the data to accurately reflect the gaps in various programs. This paper uses the TOPSIS method to evaluate the performance of the intellectual property value strategy of six typical technology companies based on three dimensions: financial performance, external performance, and value chain performance. The study found that the value chain performance was the most important in the performance evaluation of the intellectual property value strategy, followed by the external performance, and then by the financial performance. There were also significant differences in the intellectual property value strategy of the six technology companies.

1. Introduction

The 21st century is considered to be the era of the knowledge economy. Enterprises must learn to formulate a strategy for intellectual property rights, especially in the fields of science and technology. Similarly, researchers must address the issues of value creation and strategic guidance for working with intellectual property [1]. Unlike physical assets, intellectual property is inherently risky. Intellectual property is an intangible asset with a large investment and a long investment return period. However, it plays an important role in improving the competitiveness of enterprises. Some enterprises regard intellectual property as a long-term development strategy, and hence, the performance evaluation for enterprise intellectual property value strategies is particularly important. Economic globalization emphasized realistic requirements for science and technology enterprises to strengthen their research and their intellectual property strategies. In this way, the evaluation of intellectual property strategies is important for achieving technological innovation and strategic performance. This paper links intellectual property strategies and performance evaluation, aiming to help science and technology enterprises fully understand the strategic value of intellectual property and to be more effective in creating intellectual property.

Previous research has mostly focused on intellectual property management. For example, Liu and Chin proposed detailed measures for the in-depth allocation of resources in the implementation of intellectual property strategies from the perspective of auditing [2]. Similarly, Young et al. compared the intellectual property management practices in the research and development (R&D) departments of 18 universities and enterprises and summarized the strategic management problems associated with this process [3]. In addition, Hanel discussed the strategic management of intellectual property through various examples and analyzed

the evolution of American policies in in terms of intellectual property protection [4]. The value of strategic approaches to intellectual property emphasizes future interests, which scholars have been keen to evaluate [5]. Additional studies have also examined the issue of innovation and intellectual property protection [6].

In these respects, scholars have conducted much research on evaluation methods having to do with strategic performance, such as the index framework evaluation method [7], the data envelopment analysis method [8], the balanced scorecard method [9, 10], and the fuzzy evaluation method [11]. Previous studies have analyzed strategic performance from the perspectives of finance [12], product management, technological innovation, and competitiveness. Although research on the strategic performance evaluation for enterprises has produced fruitful results, it still has some limitations. The existing research pays greater attention to the construction of the evaluation index system, while focusing less on the application of the index system in practice. The TOPSIS method is a commonly used intra-group comprehensive evaluation method, which can make full use of original data. Its results can accurately reflect the gap between evaluation schemes. Therefore, this paper applies the TOPSIS method as an indicator system.

This study's main contributions to the literature are as follows. Previous studies have constructed a performance evaluation index system using a variety of methods, and the validity of these methods has been tested in several ways. This paper summarizes existing performance evaluation index systems and uses the TOPSIS method to apply the index system in a specific practice, which has a certain practical value. This study first constructed a performance evaluation index system for the intellectual property value. Second, based on the index system, the TOPSIS method was used to evaluate the performance of specific company's intellectual property value.

2. Research Method

2.1. Division of Evaluation Dimensions. Several scholars have constructed a map and index system to measure the intellectual property value strategies of high-tech enterprises [7]. In this present study, the intellectual property value strategies were evaluated based on three dimensions: (1) financial performance, (2) external performance, and (3) value chain performance. These dimensions are summarized as follows:

First, the financial performance dimension refers to the contributions of intellectual property to the financial situation of enterprises during the strategic period. It mainly includes capital structure performance and net income performance, which represent a comprehensive reflection of the intellectual property value creation activities of enterprises. Eventually, all intellectual property value creation activities will be converted into financial performance.

Second, a clear value proposition of intellectual property plays an important role in realizing the external value of the intellectual property of enterprises. The external embodiment of the performance of intellectual property value strategies is to achieve its differentiated value proposition. Intellectual property is a special right, and its value proposition can not only produce competitive advantages in terms of intellectual property for enterprises but also produce market benefits. Thus, it can form the basis for competitive market performance advantages.

Third, action is required in terms of the internal processes of intellectual property development that are carried out in order to achieve specific external value propositions and financial performance. The value chain of corporate intellectual property development activities mainly includes three aspects: (a) R&D performance, (b) the industrialization of intellectual property, and (c) intellectual property protection performance. According to the characteristics of marine science and technology enterprises, R&D experiments and the industrialization of marine intellectual property are important for the value creation process for intellectual property.

2.2. Construction of the Evaluation Index System. According to the three dimensions included in the evaluation of intellectual property value strategies discussed in Section 2.1, the index system for the performance evaluation of the intellectual property value for marine science and technology enterprises was constructed through a process of expanding indices.

In the financial performance dimension, an increase in net income refers to an increase in net profits. However, capital structure performance refers to the contributions of intellectual property to capital growth and capital structure optimization and to an increase in assets resulting from intellectual property. The essence of capital structure optimization brought about by intellectual property has to do with financing, which can be achieved through guaranteed financing for intellectual property, direct investment attracted by intellectual property, and intellectual property securitization. Therefore, two indexes were used in this dimension: the net income in terms of intangible assets, as well as intangible assets and goodwill.

In terms of external performance, the number of domestic patents refers to the number of patents applied for in China, the number of cooperative patents refers to the number of patents obtained in cooperation with other enterprises or experts, and the number of patent cooperators refers to the number of individuals who cooperate with an enterprise to develop new patents. The numbers of patents, cooperative patents, and patent cooperators can reflect the level of external performance for the intellectual property of enterprises to a certain extent. That is, the number of patents positively correlates with the quality of the external performance of an enterprise's intellectual property. Therefore, three indexes—the numbers of domestic patents, cooperative patents, and patent cooperators—were selected in order to measure the external performance of the intellectual property value strategies of enterprises.

In analyzing value chain performance, the manpower and material resources invested by enterprises in the R&D process can be measured by the numbers of R&D personnel and R&D expenditure amounts. An invention patent refers to an original, novel, and practical form of technology created by an enterprise. Among the protected objects covered by patent laws in various countries, invention patents enjoy the strictest and highest level of protection, as well as the highest technical content. Therefore, seven indexes were selected for the evaluation of value chain performance, including average patent age, numbers of R&D personnel, and R&D expenditure amounts.

To summarize, two indices of intangible assets and goodwill, as well as net income from intangible assets were employed to measure the financial performance of science and technology enterprises. In addition, to measure an enterprise's external performance, three indices were selected, including the number of domestic patents, the number of cooperative patents, and the number of patent cooperators. Finally, to measure value chain performance, seven indices were chosen, including average patent age, the number of R&D personnel, the amount of R&D expenditure, and the number of patented inventions. The index systems used for the performance evaluation of intellectual property value for science and technology enterprises are shown in Table 1.

2.3. Determination of Index Weight. The variation coefficient method is an objective weighting method in which index values are used to directly calculate a weight based on the proportion of the variation coefficient. The variation coefficient refers to the ratio of standard deviation and the mean value of index data. In this way, the weights are proportional to the amount of standardized variation in the index values for a sample. This approach is therefore suitable for index systems with ranges of values. The objective weight of each index can be obtained through the variation coefficient method according to the steps below:

(1) First, the variation coefficient CV is calculated using the formula $\mathrm{CV} = (\delta/\mu)$

(2) Second, the index weight W_i is calculated by the formula $W_i = (\mathrm{CV}/\sum_{i=1}^{n} \mathrm{CV})$

3. Results and Discussion

In this paper, we employed a traditional TOPSIS model to evaluate the performance of intellectual property value strategies for six enterprises.

3.1. Sample Selection. We selected a sample of six listed science and technology enterprises specializing in radar, communication, navigation, electronic interference and confrontation, and electronic technology products and systems. We then evaluated the performance of these companies' intellectual property value strategies according to relevant index data. The six enterprises selected were the following: (1) Beijing Highlander Digital Technology Co., Ltd., (2) Sun Create Electronics Co., Ltd., (3) SUFA Technology Industry Co., Ltd., (4) Beijing BDStar Navigation Co., Ltd., (5) Guangzhou Haige Communications Group Co., Ltd., and (6) Goertek Inc.

3.2. Data Sources. The data in this paper mainly come from the patent retrieval system of the China National Intellectual Property Administration, the Wanfang Database, the annual statements of the enterprises, and the China Intellectual Property Right Net. We note that, in the dimension of financial performance, the net income of intangible assets is equal to the intangible assets and goodwill divided by the product of the total assets and the net profit (see Table 2, for relevant data).

3.3. TOPSIS Analysis and Results. The traditional TOPSIS method is suitable for the static evaluation of two-dimensional data. The TOPSIS model constructed in this paper was used for the performance evaluation of the intellectual property value strategies for science and technology enterprises. The detailed steps are as follows:

(1) Decision matrixes were constructed and standardized.

There were m ($m = 6$) science and technology enterprises participating in the evaluation, namely, A_j ($j = 1, 2, \ldots, m$), and each marine science and technology enterprise had n ($n = 12$) indexes. Namely, C_i ($i = 1, 2, \ldots, n$). x_{ij} ($i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$) was used to represent the ith index value of the jth science and technology enterprise. Based on this information, an original index matrix R with m rows and n columns was constructed, and a new matrix $r = (\tilde{x}_{ij})_{m*n}$ was obtained by standardizing the matrix R pursuant to formulas (1) and (2):

$$\text{Benefit index: } \frac{(x - \min)}{\max - \min}, \tag{1}$$

$$\text{Cost index: } \frac{(\max - x)}{\max - \min}. \tag{2}$$

(2) The weight of each index was calculated.

The indexes were weighted using the variation coefficient method mentioned in Section 2.3. According to the specific calculation steps in 1.3, the index weights, $W_1, W_2, \ldots, W_i$, were obtained, respectively. The results of these calculations are shown in Table 3.

(3) The positive ideal solution and the negative ideal solution were determined.

Among the n indexes for science and technology enterprises, A_i, the optimal value was $x_i^+ = \max_{j=1,2,\ldots,m} x_{ij}$, and the pessimal value was $x_i^- \min_{j=1,2,\ldots,m} x_{ij}$. The positive ideal solution A^+ and the negative ideal solution A^- are, respectively, as follows:

Table 1: Performance index systems of intellectual property value for marine science and technology enterprises.

Performance dimension	Index systems
Financial performance	Intangible assets and goodwill Intangible assets' net interest
External performance	Number of domestic patents Number of cooperative patents Number of patent collaborators
Value chain performance	Average years of patent Researchers and developers R&D expenditure Chinese invention patents Chinese utility model Chinese appearance design Patent inventors

Table 2: Relevant index data of sample enterprises.

Dimension	Index	Highlander	Sun create	SUFA technology	BDstar navigation	Haige communications	Goertek
Financial performance	Intangible assets and goodwill	56194	26505	5211	163696	155227	241492
	Intangible assets' net interest	2571	430	293	20237	6634	8912
External performance	Number of domestic patents	84	1099	246	766	430	3539
	Number of cooperative patents	1	170	223	62	39	34
	Number of patent collaborators	2	168	150	66	8	6
Value chain performance	Average years of patent	5	4	2	5	4	4
	Researchers and developers	281	1297	131	1113	2525	8941
	R&D expenditure	3038	11911	4471	21977	67778	180680
	Chinese invention patents	53	542	197	397	193	2536
	Chinese utility model	19	518	48	248	146	986
	Chinese appearance design	12	39	1	121	91	17
	Patent inventors	62	195	200	200	200	199

Table 3: Calculation results of index weights.

Performance dimension	Index	Weights W_i
Financial performance	Intangible assets and goodwill	0.0702
	Intangible assets' net interest	0.0404
External performance	Number of domestic patents	0.1059
	Number of cooperative patents	0.0784
	Number of patent collaborators	0.0909
Value chain performance	Average years of patent	0.0449
	Researchers and developers	0.1151
	R&D expenditure	0.1189
	Chinese invention patents	0.1218
	Chinese utility model	0.0932
	Chinese appearance design	0.0822
	Patent inventors	0.0382

Table 4: Performance evaluation results of intellectual property value strategy.

Enterprise name	Financial performance dimension evaluation value	Ran king	External performance dimension evaluation value	Ran king	Value chain performance dimensions evaluation value	Ran king	Comprehensive evaluation value	Ranking
Highlander	0.0790	5	0.0208	2	0.0146	3	0.0644	5
Sun create	0.0789	6	0.0107	5	0.0090	5	0.0643	6
SUFA technology	0.0794	4	0.0171	3	0.0137	4	0.0651	4
BDstar navigation	0.0814	3	0.0018	6	0.0024	6	0.0655	3
Haige communications	0.0844	2	0.0109	4	0.0282	2	0.0705	2
Goertek	0.0955	1	0.0839	1	0.1038	1	0.0983	1

Notes: the smaller the ranking value, the better the performance of the company's intellectual property strategy.

$$A^+ = (x_1^+, x_2^+, \ldots, x_n^+),$$
$$A^- = (x_1^-, x_2^-, \ldots, x_n^-). \quad (3)$$

(4) The index data were weighted using formula (4). The weighted Euclidean distance between marine science and technology enterprises and the positive and negative ideal solutions were calculated using formulas (5) and (6):

$$v_{ij} = w_i * x_{ij}, \quad (4)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - x_i^-\right)^2}, \quad (5)$$

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - x_i^+\right)^2}, \quad (6)$$

where v_{ij} represents the weighted index value for the ith index of the jth marine science and technology enterprise, w_i represents the weight of the index C_i, and d_i^+ and d_i^- represent the weighted Euclidean distance between enterprise A_i and the positive ideal solution A^+ and the negative ideal solution A^-, respectively.

(5) The similarity between each enterprise and the ideal solutions were calculated using formula (7).

The formula for calculating the deviation from the ideal solution is

$$U_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad (7)$$

where U_i reflects the degree to which science and technology enterprises deviated from the negative ideal solution. If $U_i = 1$, then $A_i = A^+$; if $U_i = 0$, then $A_i = A^-$. The closer the value of U_i was to 1, the closer the enterprise was to the positive ideal solution, indicating better performance in terms of the enterprise's intellectual property value strategies. In this way, the financial performance, external performance, value chain performance, and comprehensive performance evaluation values of the intellectual property value strategies for m sample enterprises were calculated, as shown in Table 4.

The results in Table 4 show that, among the six sample enterprises, Goertek Inc. topped the list in terms of financial performance, external performance, value chain performance, and comprehensive ranking of its intellectual property. It also had absolute advantages over the other five enterprises considering external performance and value chain performance. This indicates that financial performance, external performance, value chain performance, and comprehensive performance for the intellectual property value of Goertek Inc. were close to ideal. Goertek Inc. also enjoys a generally high value of intangible assets, good overall income, and high income from intangible assets. By making the largest investment in R&D, the company clearly valued its importance, a fact reflected in the high quality and quantity of its patents. In contrast with Goertek Inc., Sun Create Electronics Co., Ltd. and Beijing BDStar Navigation Co., Ltd. ranked lower in terms of financial performance, external performance, value chain performance, and comprehensive performance of intellectual property. In addition, both companies were weak in the above dimensions, as reflected by net income of intangible assets, R&D investment, etc.

4. Conclusion

In this paper, an index system for the performance evaluation of intellectual property value strategies was constructed based on three dimensions: (1) financial performance, (2) external performance, and (3) value chain performance. Our index system was comprised of 12 indexes, including the intangible assets and goodwill, the net income from intangible assets, the number of domestic patents, the number of cooperative patents, the number of patent cooperators, the average patent age, the number of R&D personnel, the amount of R&D expenditure, the invention patents, the utility model patents, the design patents, and the patent inventors. In our analysis, we used a TOPSIS model based on this evaluation index system, and we examined a sample of six listed science and technology enterprises in China in order to calculate performance evaluation scores for their intellectual property value strategies. The results of this empirical research show that it

is feasible to use the TOPSIS model to evaluate intellectual property value strategies for science and technology enterprises.

Data Availability

All data have been included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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