On multistage flexible comprehensive evaluation of complicated system*

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Abstract: The paper analyzed characters of complicated system and discussed the reason of comprehensive evaluation, realization of flexible comprehensive evaluation was researched from prospect of dynamic measure selection of evaluation, balance of functionality and harmony, uncertainty factor. In the end, multistage flexible comprehensive evaluation of complicated system was applied to performance evaluation of firm.

Key words: complicated system; multistage; flexible comprehensive evaluation.

1. Introduction

In the process of human transformation of nature, we often encountered in a number of programs to determine the merits of the decision-making and selection problems, and comprehensive evaluation is an important support of decision-making, comprehensive evaluation problem is an important aspect of multi-attribute decision making research (Fabrizio & Roberto, 2003). Things tend to have more than one feature attribute vector, in the decision-making process requires a combination of each feature attribute vector of things to judge, which is the comprehensive evaluation. Comprehensive evaluation in practice is universal, different choices of assessment systems for evaluation of things have different evaluation results, the comprehensive evaluation is an integration process of subjective information and objective information, which determines the complexity of evaluation. The complexity of real life determine the relationship between things is often nonlinear, comprehensive evaluation is no exception, the overall evaluation model of comprehensive evaluation can be divided into the sub-linear and nonlinear evaluation. It has a good approximation mapping relation and a rapid large-scale data operation, as the development of artificial intelligence technology, it has also been widely used in the field of evaluation, such as neural networks can approximate any mapping (Simon, 2001), has been widely used in practical comprehensive assessment.

2. The characteristics of comprehensive evaluation of complicated system

2.1 The characteristics of multi-level complex system of evaluation objects

Only the number of evaluated systems greater than 1, it has the necessary to evaluate and select, evaluation of the system has the general system characteristics, such as the relative stability and openness, we use S as the vector space of evaluation system. Evaluation of the system vector $S = (S1, S2, S3, ..., Sn)$, $n > 1$, $S \in S$. With the

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multilevel nature of the evaluation system, evaluation system is constituted by a number of sub-systems.

2.2 Objective evaluation of multi-level system

The same thing on the evaluation have different purposes and different evaluation results, the purpose was to evaluate the root of the problem, we use G as the evaluation vector space, the evaluation of the target vector $G = (G1, G2, G3, ..., Gm)$, $G \in G$. The evaluation of the target also has a multilevel nature, it is constituted by a number of sub-goals.

2.3 Evaluation of the properties of multi-level system

There are many characteristics differ from the other things, the evaluation attribute is the characteristics to distinguish between things, we use A as the vector space of evaluation attribute, the evaluation attribute vector $A=\{A1,A2,A3,\ldots Ap\}$, $A \in A$. Evaluation attribute also has a multilevel nature, It is constituted by a number of sub-systems. Evaluation attribute are generally efficiency, cost, interval and fixed, in the process of comprehensive evaluation, various types of properties need to be dimensionless.

2.4 Multilevel nature of the standard attributes

Different stages have different assessment purposes, the reference standard for evaluation must be appropriate to determine the scope of attribute changes, comprehensive evaluation has the characteristic of relativity, the reference standard can be internal longitudinal or external lateral. Based on the evaluation purposes, we often combine both methods to determine the reference standard of evaluation attributes.

3. The motivation of flexible comprehensive evaluation

First, the reality of complex system has a multilevel nature of the evaluation objectives, evaluation of complex systems with different goals lead to the evaluation criteria and attributes of the design is different, only in this way can provide targeted decision support for practice; Second, as time went on, the system continuously exchange matter and energy with the outside world, the dynamic characteristics of complex systems will make the appropriate changes to the evaluation objectives and standards of complex systems, the results is complex and must be adjusted according to actual situation, since each evaluation attribute has different stages and different evaluation objectives, the comprehensive and coordinated development of evaluation attribute and the dominant characteristic of key attributes will be different, that is, the function and coordination of comprehensive evaluation; Finally, when the evaluation process related to future uncertainties in development, its function and coordination of evaluation, evaluation criteria and the weight vector, etc. should be adjusted accordingly. The evaluation result is an integration process of subjective information and objective information, for different target vector, weight vector of evaluation results is uncertain, therefore, we need to analyze and diagnose the evaluation results.

4. The realization of multistage flexible comprehensive evaluation

4.1 The dynamic selection of multilevel and multistage of evaluation index based on the goal of comprehensive evaluation of complicated systems

4.1.1 Different objectives, attributes for decision-making and the choices of reference standard

Evaluation of complex systems with different goals, the relevant decision attributes and their choice of methods for reference standard should be different (Gershon, 1984). Index feature selection methods contains frequency statistics, theoretical analysis, expert consultation and so on.

4.1.2 Dynamic diagnosis of index selection

In the course of the comprehensive evaluation, index selection is to simplify the evaluation work and improve work efficiency. We can conduct indicator selection when the indexes have greater relevance, although some indicators changed little and have little effect on the evaluation results, it must be selected. Methods are often used multivariate statistical methods (such as principal components), grey theoretics (grey relevance, grey situation decision-making, etc.), fuzzy sets and rough sets and other methods. However, relevant filtering may filter out key indicators, the indicators with little change may be changed over time and gradually increase the range of change, therefore, the dynamic tracking and diagnose of time series is needed to make up important evaluation index in time.

4.1.3 The flexible of index weights

There are many methods for index weights, such as the analytic hierarchy process (AHP), the chain score method (CCM), comparison matrix method (CMM), entropy weights, multi-objective programming and combination weighting method, etc., many are based on a combination of subjective and objective methods, there is a corresponding change range for each index weight, the weight value will has significant influence on results (Brans, Vincke & Mareschal, 1986), therefore, the weight of indicators need to be dynamically adjusted.

4.2 Comprehensive evaluation of complex systems based on functional balance and coordination

The functional comprehensive evaluation stresses the stability of the state and if the system operation of the basic functions are satisfied; It is more emphasis on the coordinate state of development between the operation function of system, the coordination make the system more stable. In the comprehensive evaluation process, according to the stage goal to find a balance between them. In the design process, we use a comprehensive nonlinear evaluation method for some important functional evaluation attributes. While for the higher requirements of indicator on overall, we use the linear evaluation method. The general model of comprehensive evaluation as in:

$$f(x_i) = \prod_{h}^{a_1} g_h(x_h)(x_h \bullet r_h)^{w_h} \bullet [\sum_{j}^{a_2} g_j(x_j) \bullet w_j \bullet x_j \bullet r(x_j)] \quad (1)$$

$g_h(x_h)$ and $g_j(x_j)$ is the incentive (or penalty) operator, r_h and $r(x_j)$ is the reference standard operator, $h+j=i$. The function value will take 1 when the value changes in a certain range. When the attribute value below a certain value or above a certain value, the function value will increase (for excitation) or decrease (the implementation of punishment) accordingly. This is because when some values increase to a certain extent, it is very difficult to make more progress, or when an attribute value below a certain range, the security of the system will bring a major impact. It also greatly impact the development of the system, this is an important aspect of nonlinear, w_h, w_j, x_h, x_j is the weight vector and the attribute vector, the function consists of two parts, one of which is the comprehensive evaluation of the linear part $\sum_{j}^{a_2} g_j(x_j) \bullet w_j \bullet x_j \bullet r(x_j)$, the other part is the comprehensive evaluation of nonlinear $\prod_{h}^{a_1} g_h(x_h)(x_h \bullet r_h)^{w_h}$, on both sides of equation (1) by taking the natural logarithm can transform the nonlinear part into linear.

4.3 The uncertainty of complex systems based on multi-stage flexible comprehensive evaluation

Comprehensive evaluation as an effective tool for decision support, its results provide the direct basis for decision-making, while any decision has risks, a particular indicator is very important at present but may be unimportant in the future. Similarly, some indicators may be not important at present but in the future may

become the decisive factor for decision-making. Uncertainty analysis paradigm as:

$$f(x_i,\Theta_j)=\prod_{m_1}^{b_1} g_{m_1}(x_{m_1})\bullet(x_{m_1}\bullet r_{m_1})^{w_{m_1}}\prod_{m_2}^{b_2} g_{m_2}(\Theta_{m_2})\bullet(\Theta_{m_2}\bullet r_{m_2})^{w_{m_2}}\bullet u(\Theta_{m_2})\bullet [\sum_{m_3}^{b_3} g_{m_3}(x_{m_3})\bullet(w_{m_3}\bullet x_{m_3}\bullet r_{m_3})+w_{m_4}\bullet\Theta_{m_4}\bullet r_{m4}\bullet v(\Theta_{m_4})] \tag{2}$$

$u(\Theta_{m_2})$ and $v(\Theta_{m_4})$ is the uncertainty operator, the other letters have same meanings as above, in the actual evaluation process, it should be made to minimize future risks and maximize the evaluation utility, to predict the probability of occurrence of vector space for each uncertainly factor, and to re-evaluate the larger probability factors and the factors that influenced. We introduce the Bayesian decision-making formula, uncertainty evaluation model can be expressed as:

$$f(x_i,\Theta_j)=\prod_{m_1=1}^{c_1} g_{m_1}(x_{m_1})\bullet(x_{m_1}\bullet r_{m_1})^{w_{m_1}}\bullet\prod_{m_2=1}^{c_2} g_{m_2}(\Theta_{m_2})\bullet(\Theta_{m_2}\bullet r_{m_2})^{w_{m2}}\bullet[\sum_{m_3=1}^{c_4} P(\Theta_{m_2}|a_{m_3})]\bullet P(a_{m_3})\bullet[\sum_{t_1}^{c_5} g_{t_1}(x_{t_1})\bullet w_{t_1}\bullet x_{t_1}\bullet r_{t_1}+\sum_{t_2}^{c_6} g_{t_2}(\Theta_{t_2})\bullet w_{t_2}\bullet\Theta_{t_2}\bullet r_{t_2}\bullet(\sum_{t_3}^{c_7} P(\Theta_{t_2}|b_{t_3})\bullet P(b_{t_3}))] \tag{3}$$

4.4 The syncretic technology of objective information and subjective information based on artificial intelligence

Artificial intelligence in large-scale data processing has the advantage of strong computing capabilities, can approach any mapping well, so operated indicators, weights and comprehensive evaluation by combining artificial intelligence have strong support.

(1) Because of the complexity of the complicated system, in the process of fusion of subjective information and objective information, different evaluation objectives and evaluation of property is not the mapping of one to one, using artificial intelligence techniques to imitate the fusion of subjective information and objective information in the evaluation process of complicated systems, improve the effectiveness and efficiency of the attributes selection of comprehensive evaluation in complicated systems.

(2) Determination of weights is an important process in the process of comprehensive evaluation of complicated systems. There are many methods of determining weights, determination of weights is an important part in the system of comprehensive evaluation of complicated systems, using artificial intelligence technology can imitate the process that determine weights through the fusion of subjective information and objective information in the evaluation process of complicated systems, thus improving the efficiency of comprehensive evaluation of complicated systems.

(3) Comprehensive evaluation of complicated systems and complicated systems in the past (history) are inextricably linked, and also have the exchange of matter and energy with the external environment of system, and the complicated systems are constrained by its future development, with the increasing of subjective information and objective information of complicated systems, put forward the higher requirement of the fusion of subjective information and objective information, so the data processing capabilities of artificial intelligence provides support for large operations of the comprehensive evaluation of complicated systems.

At present, the common methods used in artificial intelligence are Artificial Neural Network, Genetic Algorithm, Machine Learning and so on.

5. The application of multistage flexible comprehensive evaluation of complicated systems in business performance evaluation

Based on the theory of business performance, combined with comprehensive evaluation of complicated systems, we build multistage flexible evaluation system of business performance (see Table 1). Balanced score card (Robert & David, 1996) is a typically enterprise performance evaluation system, which provides performance evaluation with a general analytical framework, the author puts the model of enterprise performance evaluation into four stages: In the first stage, the enterprise performance evaluation in different stages of development, in early phase, the interests of owners of capital dominate, the increase of capital value is the main objective of this phase, namely, financial goals is the main objective of this phase. The main indicators of enterprise performance evaluation in addition to our selection of indicators related to financial evaluation, we also selected the key indicators of business process and technology innovation at three levels, and the function of indicators is dominant, so we use linear integrated evaluation model; In the second stage, with business development, business performance evaluation not only considers the main stakeholders, but also considers other important stakeholders such as employees, customers, and social dimensions, these evaluation indicators should be put into the evaluation model, strategic objectives are the key aspects of enterprise performance evaluation, Enterprises should mainly focus on their comprehensive and coordinated development, and therefore evaluation model is nonlinear evaluation model; In the third stage, with the development of business, enterprises have accumulated rich experience, have achieved good financial performance, and the management system have be further regulated, Enterprises need to further expand the business scope, technological innovation, the quality of staff, the feedback of customer information in marketing, in this stage, the model of comprehensive evaluation adopts excitation function in the indicators of technology innovation, and gradually builds the core competitiveness of enterprises; In the fourth stage, with the company's business success, the process of running appears new problems and cannot meet strategic environment of enterprise, enterprise needs timely diagnosis, identify the key factors of impacting business performance, then after we introduce incentive factor and in order to improve the early warning of strategic, comprehensive evaluation model introduce uncertainty factors, to control the critical evaluation, so as to better promote the company's fully operational, and build a sustainable advantage of competitive business.

Based on the fourth stage of business development, we take the nurture of sustained competitive advantage as the enterprise's strategic objectives, to evaluate the performance of the business, comprehensive evaluation index determined by expert analysis. The radar shown of business-critical evaluation is shown in Fig. 1, in the process of comprehensive evaluation, for the rate of new product sales more than expectations, we introduce incentive factors and introduce uncertainty factor into the future development of R&D alliance, the data of enterprise flexible comprehensive evaluation are shown in Table 2, using integrated assessment model:

$$Performance = \sum_{i=1}^{10} g_i(x_i) \bullet u_i(x_i) \bullet w_i(x_i) \bullet \frac{x_i - Min(x_i)}{Max(x_i) - Min(x_i)}$$

The result of evaluation that through flexible comprehensive evaluation is 0.708207, the overall business performance is better, and achieved good effect on the key indicators—the rate of new products sales.

Table 1 Performance evaluation of flexible multi-stage evaluation system

Stage	A higher objective	A lower objective	Index level	Evaluation model
The first stage	Financial strategic objectives	The added value of capital	Level indicators of financial	Linear comprehensive evaluation
		Business process optimization	Business process level indicators	
		Technology innovation	Indicators of technology innovation	
The second stage	The strategic objectives of key stakeholders	Financial goals	Level indicators of financial	Nonlinear comprehensive evaluation
		Employee satisfaction	Staff level indicators	
		Customer satisfaction	Customer level indicators	
		Establish a good social effect	Environmental aspects of social indicators	
		Business process optimization	Business process level indicators	
		Technology innovation	Indicators of technology innovation	
The third stage	Strategic goal of core competence	Financial goals	Level indicators of financial	The mixed comprehensive evaluation model after introduce the incentives (penalties) operator
		Employee satisfaction	Key indicators of employee level	
		Customer satisfaction	Key indicators of the customer level	
		Social effects	Environmental aspects of social indicators	
		Business process optimization	Key indicators of the business process level	
		Technology innovation	Key indicators of technology innovation	
The fourth stage	Strategic objectives of sustainable competitive advantage	Financial goals	Level indicators of financial	The mixed comprehensive evaluation model after introduce the incentive operators and uncertainty operator
		Employee satisfaction	Key indicators of employee level	
		Customer satisfaction	Key indicators of the customer level	
		Social effects	Environmental aspects of social indicators	
		Business process optimization	Key indicators of the business process level	
		Technology innovation	Key indicators of technology innovation	

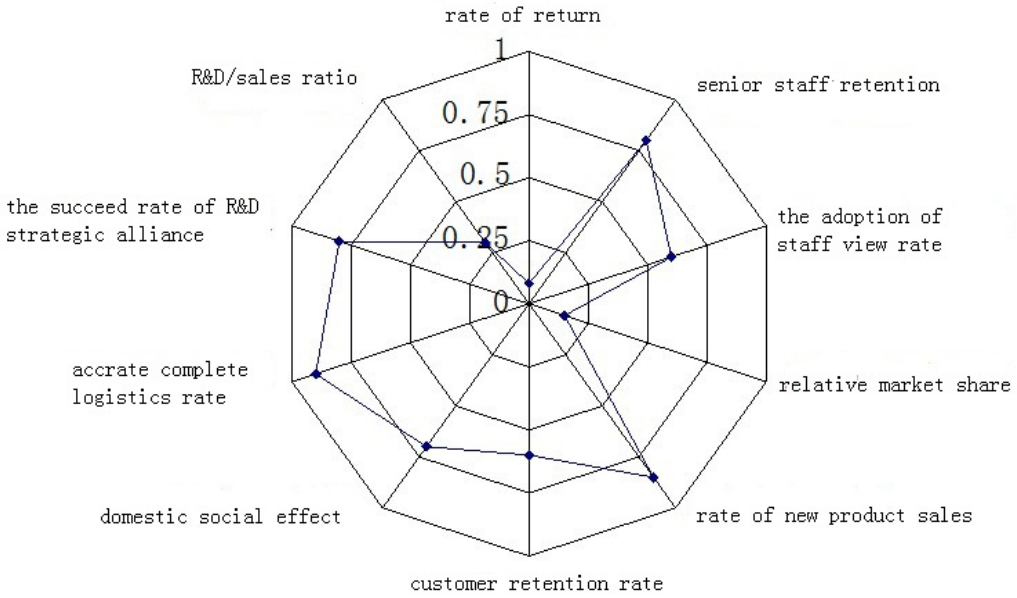

Fig. 1 The key indicators of sustainable competitive advantage radar

Table 2 Enterprise flexibility comprehensive evaluation

Indicator	Indicator			Weight coefficient	Incentive operators	Uncertainty operator	Comprehensive evaluation value performance
Indicator	Index value x_i	Reference standard Min(x_i)	Reference standard Max(x_i)	$w_i(x_i)$	$g_i(x_i)$	$u_i(x_i)$	
Rate of return	0.08	0	0.45	0.09	1	1	
Senior staff retention	0.8	0.3	1	0.11	1	1	
The adoption of staff view rate	0.6	0	1	0.08	1	1	
relative market share	0.15	0.01	0.3	0.1	1	1	
Rate of new product sales	0.85	0.05	1	0.14	1.5	1	
Customer retention rate	0.6	0.3	0.8	0.09	1	1	0.708207
Domestic social effect	0.7	0.05	1	0.1	1	1	
Accurate complete logistics rate	0.9	0.5	1	0.08	1	1	
The success rate of R&D strategic alliance	0.8	0.1	1	0.13	1	0.6	
R&D/Sales ratio	0.3	0.02	0.4	0.08	1	1	

6. Conclusion

Comprehensive evaluation is a very classical problem of multiple attribute decision making, is subjective information and objective information integration process, the comprehensive evaluation reflecting thought of system, both stressed the functionality, but also stressed that overall, in the system，it exists complex relationship between the various variables, and the system is open, the continuously exchange of material and energy between system and the outside world is the premise of improving the stability of the system, which determines the system dynamic characteristics, it provides decision-making control and decision-making diagnosis in actual work with important decision support. A simple evaluation system and immutable evaluation system cannot provide the running of complicated systems with good decision-making information, the idea of flexible integrated assessment system more in line with the real world decision-making.

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