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A Management Performance Evaluation Model of Science & Technology Enterprise Incubator Based on Extension Membership Degree

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Abstract

Management of science & technology enterprise incubator is complicated with much uncertainty. Its performance is hard to be measured accurately. Therefore, this paper analyzes key factors that influence the management performance evaluation of incubators and constructs a management performance evaluation system. It proposes an improved extension membership degree evaluation model of science & technology enterprise incubator based on extension theory. This model puts in place extension distance and extension side-distance of management performance evaluation indicator and works out corresponding extension correlation function and weighted extension membership degree. Through a case study, the model and the algorithm are proved to be effective and feasible.

Keywords: Science & Technology Enterprise; Management Performance; Extension Membership Degree; Evaluation Model.

1. INTRODUCTION

With the development of science and technology, hi-tech science & technology enterprise incubators grow at a staggering pace. These incubators are not only able to provide enterprises with qualified services of business counseling, business prediction and suggestions on financing, but also help them with technical analysis, business policy advice and entrepreneurial technical route planning. As a result, the emerging technological start-ups have a higher possibility of survival and success and effectively reduce the risk of failure.

However, many factors need to be taken into consideration to realize the purpose of enterprise incubators, both internal factors such as operation and external factors. The management of incubator is a complicated and fuzzy decision-making process. It is significant to effectively evaluate the management performance of incubator and make improvements to enable a sustainable development of science & technology enterprise incubator.

Many researchers have studied the performance evaluation of incubator with some achievements (Zhang and Zhan, 2010; Liu, 2011; Sun and Zhang, 2005; Xu et al., 2006). But these researches are more or less focused on specific objectives with certain limitations. Thus, based on previous progress, this paper proposes an improved management performance evaluation model from the perspective of extension membership degree (Cai and Yang, 2013; Yang and Cai, 2012; Wang et al., 2013; Wang et al., 2014; Lei and Qiu, 2013; Li et al., 2013).

2. MANAGEMENT PERFORMANCE EVALUATION SYSTEM OF SCIENCE & TECHNOLOGY ENTERPRISE INCUBATOR

Two aspects hold key to the effective evaluation of management performance. One is to put in place an effective indicator system. The other is to conduct quantitative measurement based on evaluation model or algorithm with high reliability. Therefore, the selection of indicators should be scientific, objective, guidable comprehensive and significant.

The principle of "being scientific" means that indicators selected should have significance and the selection process should be reasonable. The principle of "being objective" suggests that indicators are selected according to objective facts rather than subjective arbitrary. The principle of "being guidable" means indicators selected should provide guidance for the sustainable development of enterprise incubators. The principle of "being comprehensive" means to avoid bias and one-sidedness in indicator selection. The principle of "being significant" instructs to select key indicators rather than irrelevant ones. Based on these principles, this paper works out a new type of management performance evaluation indicator system to serve the analysis effectively, as is shown in Table 1.

Table 1 Management performance evaluation indicator system of science & technology enterprise incubator

Target layer	Criterion layer	Indicator layer
Management performance evaluation index system of science & technology enterprise incubator	Incubating development ability	Percentage of success of incubating enterprises
		Number of incubating enterprises
		Incubating profit
		Percentage of survival of incubating enterprises
	Technological innovation ability	Scientific achievement
		Technical transformationability
		Training and learning ability
		Number of cooperation projects of education combined with research and products
	Economic performance	Cost of incubating
		Resource utilization rate of incubating
		Growth rate of income of the incubating enterprise
	Social-profit performance	Employment growth rate
		Industrial value-added rate of incubating enterprises
		Lifting force of soft environment of incubating enterprises
		Lifting force of hard environment of incubating enterprises

3. MANAGEMENT PERFORMANCE EVALUATION MODEL BASED ON EXTENSION MEMBERSHIP DEGREE

3.1. Indicators of management performance evaluation

From Table 1, it is clear that there are three types of evaluation indicators, namely, normal indicator, backward indicator and moderate indicator. Some indicators can describe the value accurately, while other needs fuzzy qualitative descriptions. There is a necessity to transform the backward and moderate indicators to normal indicators and qualitative ones to quantitative ones so as to effectively analyze the evaluation process.

For fuzzy qualitative description indicators, this paper uses the scale of 1-9 to do the quantitative description. 1 refers to that the indicator is the least important to management performance and 9 refers to the most important to management performance. Numbers fall between 1-9 refer to the influence of indicators to management performance to different degree.

If the corresponding evaluation indicator*j* of incubator of type *i* is a backward indicator, its value of a quantity is $v_i(j)$, then the transformed value of a quantity as normal indicator is $u_i(j)$. There is:

$$u_i(j) = \min_{1\le i\le n}\left(v_i(j)\right)/v_i(j) \tag{1}$$

In particular, if the corresponding evaluation indicator *j* of incubator of type*i* is a backward indicator, its value of a quantity is $v_i(j)=[v_i^{min}(j), v_i^{max}(j)]$, then the transformed value of a quantity $u_i(j)$ as normal indicator is:

$$\begin{aligned} u_i(j) &= \left[u_i^{min}(j), u_i^{max}(j)\right] \\ &= \left[\min_{1\le i\le n}\left(v_i(j)\right)/v_i^{min}(j), \min_{1\le i\le n}\left(v_i(j)\right)/v_i^{max}(j)\right] \end{aligned} \tag{2}$$

If the corresponding evaluation indicator *j* of incubator of type *i* is a moderate indicator, its value of a quantity is $v_i(j)$, then the transformed value of a quantity $u_i(j)$ as normal indicator is:

$$u_i(j) = \min_{1\le i\le n}\left(v_i(j), v_i^0(j)\right)/\max_{1\le i\le n}\left(v_i(j), v_i^0(j)\right) \tag{3}$$

In the expression, $v_i^0(j)$ is the given value of a quantity for moderate indicator.

In particular, if the corresponding evaluation indicator *j* of incubator of type *i* is a moderate indicator, its value of a quantity is $v_i(j)=[v_i^{min}(j), v_i^{max}(j)]$, then the transformed value of a quantity $u_i(j)$ as normal indicator is:

$$\begin{aligned} u_i(j) &= \left[u_i^{min}(j), u_i^{max}(j)\right] \\ &= \left[\min_{1\le i\le n}\left(v_i^{min}(j), v_i^0(j)\right)/\max_{1\le i\le n}\left(v_i^{max}(j), v_i^0(j)\right), \min_{1\le i\le n}\left(v_i^{max}(j), v_i^0(j)\right)/\max_{1\le i\le n}\left(v_i^{max}(j), v_i^0(j)\right)\right] \end{aligned} \tag{4}$$

3.2 Extension distance of management performance evaluation indicator

If the value of quantity of evaluation indicator *j* of enterprise incubator *p* is point value $v_p(j)$, then the extension distance $\rho_i^p(j)$ of evaluation performance *i* about evaluation indicator j is:

$$\rho_i^p(j) = \left|v_p(j) - \frac{v_i^{min}(j)+v_i^{max}(j)}{2}\right| - \frac{v_i^{max}(j)-v_i^{min}(j)}{2} \tag{5}$$

If $v_p(j)=(v_i^{min}(j)+v_i^{max}(j))/2$, then $\rho_i^p(j)$ is the minimum value, which means $v_p(j)$ is the closest to $v_i(j)$. At this moment, the optimal point $v_i^0(j)$ of evaluation indicator j is at the middle of the interval $v_i(j)=[v_i^{min}(j), v_i^{max}(j)]$, that is, $v_i^0(j)=v_p(j)=(v_i^{min}(j)+v_i^{max}(j))/2$.

If the optimal point is not at the middle of the indicator interval $v_i(j)=[v_i^{min}(j), v_i^{max}(j)]$ and if it fits $v_i^0(j)\in[v_i^{min}(j), ((v_i^{min}(j)+v_i^{max}(j))/2)]$, then the extension distance $\rho_i^p(j)$ of evaluation performance type i about evaluation indicator j is a left side-distance and is expressed by:

$$\rho_i^p(j)=\begin{cases} v_i^{min}(j)-v_p(j) & v_p(j)\le v_i^{min}(j) \\ \dfrac{\left(v_i^{max}(j)-v_i^O(j)\right)*\left(v_p(j)-v_i^{min}(j)\right)}{v_i^{min}(j)-v_i^O(j)} & v_p(j)\in\left(v_i^{min}(j),v_i^O(j)\right) \\ v_p(j)-v_i^{max}(j) & v_p(j)\ge v_i^O(j) \end{cases} \tag{6}$$

If the optimal point is not at the middle of the indicator interval $v_i(j)=[v_i^{min}(j), v_i^{max}(j)]$ and if it fits $v_i^0(j)\in[((v_i^{min}(j)+v_i^{max}(j))/2), v_i^{max}(j)]$, then the extension distance $\rho_i^p(j)$ of evaluation performance type i about evaluation indicator$j$ is a right side-distance and is expressed by:

$$\rho_i^p(j)=\begin{cases} v_i^{min}(j)-v_p(j) & v_p(j)\le v_i^O(j) \\ \dfrac{\left(v_i^{min}(j)-v_i^O(j)\right)*\left(v_i^{max}(j)-v_p(j)\right)}{v_i^{max}(j)-v_i^O(j)} & v_p(j)\in\left(v_i^O(j), v_i^{max}(j)\right) \\ v_p(j)-v_i^{max}(j) & v_p(j)\ge v_i^{max}(j) \end{cases} \tag{7}$$

In particular, if the value of quantity of enterprise incubator p about evaluation indicator j is an interval value$v_p(j)=[v_p^{min}(j), v_p^{max}(j)]$, for $v_i^0(j)\in[v_i^{min}(j), ((v_i^{min}(j)+v_i^{max}(j))/2)]$, the extension distance $\rho_i^p(j)$ of evaluation performance type i about evaluation indicator j is a left side-distance and is expressed by:

$$\rho_i^p(j)=\begin{cases} v_i^{min}(j)-v_p^{min}(j) & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\le v_i^{min}(j) \\ \dfrac{\left(v_i^{max}(j)-v_i^O(j)\right)*\left(v_p^{min}(j)-v_i^{min}(j)\right)}{v_i^{min}(j)-v_i^O(j)} & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\in\left(v_i^{min}(j),v_i^O(j)\right) \\ v_p^{max}(j)-v_i^{max}(j) & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\ge v_i^O(j) \end{cases} \tag{8}$$

Similarly, if the value of quantity of enterprise incubator p about evaluation indicator j is an interval value $v_p(j)=[v_p^{min}(j), v_{maxp}(j)]$, for $v_i^0(j)\in[((v_i^{min}(j)+v_i^{max}(j))/2), v_i^{max}(j)]$, the extension distance $\rho_i^p(j)$ of evaluation performance type i about evaluation indicator j is a right side-distance and is expressed by:

$$\rho_i^p(j)=\begin{cases} v_i^{min}(j)-v_p^{min}(j) & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\le v_i^O(j) \\ \dfrac{\left(v_i^{min}(j)-v_i^O(j)\right)*\left(v_i^{max}(j)-v_p^{max}(j)\right)}{v_i^{max}(j)-v_i^O(j)} & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\in\left(v_i^{min}(j),v_i^{max}(j)\right) \\ v_p^{max}(j)-v_i^{max}(j) & \dfrac{v_p^{min}(j)+v_p^{max}(j)}{2}\ge v_i^{max}(j) \end{cases} \tag{9}$$

3.3 Extension membership degree of management performance evaluation indicator

After the extension distance $\rho_i^p(j)$ (j) is calculated, we can construct the extension correlation function $K_i^p(j)$ (j) of enterprise incubator p about evaluation indicator j and evaluation performance type i:

$$K_i^p(j)=\begin{cases}-\dfrac{\rho_i^p(j)}{\left|v_i^{max}(j)-v_i^{min}(j)\right|} & v_p(j)\in v_i(j)\\ 0 & \rho_o^p(j)-\rho_i^p(j)=0\\ \dfrac{\rho_i^p(j)}{\rho_o^p(j)-\rho_i^p(j)} & v_p(j)\notin v_i(j)\end{cases} \tag{10}$$

In the expression, ρ_0^p (j) refers to the extension distance between $v_p(j)$and $v_o(j)=\left[\min\limits_{1\le i\le m} v_i^{min}(j), \max\limits_{1\le i\le m} v_i^{max}(j)\right]$. The calculation process and formula is the same from (1) to (9).

Therefore, we can get the extension membership degree EMD_i^p of enterprise incubator$p$ about all evaluation indicators and evaluation performance type i:

$$EMD_i^p=\frac{1}{N}\sum_{j=1}^{N}K_i^p(j) \tag{11}$$

If evaluation indicators have different weights from each other, then the extension membership degree EMD_i^p is expressed as:

$$EMD_i^p=\sum_{j=1}^{N}\left(w_j * K_i^p(j)\right) \tag{12}$$

Therefore, we can get the grade of the management performance of the enterprise incubator according to the extension membership degree, as is shown in formula (13),

$$EMD_{max}=\max\left(EMD_1^p, EMD_2^p, \cdots, EMD_m^p\right)=EMD_s^p \tag{13}$$

Then, EMD_s^p 's corresponding management performance type s is the grade of the enterprise incubator p. The grade can be used for improvement and further planning of the incubator management.

The algorithm of the management performance evaluation model of science & technology enterprise incubator based on extension membership degree is described as follows:

Step 1: Abide by certain principles for indicator selection, find out key factors that influence the evaluation and construct the management evaluation indicator system;

Step 2: Consult with related experts and categorize the grade of management performance according to real situation of incubators;

Step 3: Standardize evaluation indicators according to formula (1) to (4);

Step 4: Acquire the value of quantity of the management performance about the evaluation indicator. Use formula (5) to (9) to calculate the extension distance of the management performance about different evaluation indicators and the management performance type;

Step 5: Acquire the extension correlation function of the enterprise incubator about evaluation indicator j and evaluation performance type i according to formula (10);

Step 6: Acquire the extension membership degree between the management performance and the management performance type according to formula (11) or (12) and get the grade of the management performance of the enterprise incubator according to formula (13).

4. CASE STUDY AND TEST

Management performance of one new emerging hi-tech enterprise incubator in the economic development zone is selected as the objective of the case study to test the model and the algorithm. Through on-the-spot surveys, questionnaires and experts opinions, the weights of evaluation indicators are determined, as is shown in Table 2.

Table 2 Management performance evaluation indicators of science & technology enterprise

Criterion layer	Weight	Indicator layer	Weight	Latest incubating data	Grade of management performance		
					Grade I	Grade II	Grade III
Incubating development ability	0.30	Percentage of success of incubating enterprises	0.25	0.75	0.8-1.0	0.6-0.8	0-0.6
		Number of incubating enterprises	0.20	33	30-50	15-30	0-15
		Incubating profit	0.30	0.85	0.8-1.0	0.6-0.8	0-0.6
		Percentage of survival of incubating enterprises	0.25	0.65	0.8-1.0	0.6-0.8	0-0.6
Technological innovation ability	0.25	Scientific achievement	0.25	12	20-40	8-20	0-8
		Technical transformationability	0.30	0.35-0.45	0.7-1.0	0.4-0.7	0-0.4
		Training and learning ability	0.20	0.75-0.85	0.6-1.0	0.6-0.8	0-0.6
		Number of cooperation projects of education combined with	0.25	7	10-25	5-10	0-5

		research and products					
Economic performance	0.25	Cost of incubating	0.30	80	0-50	50-120	120-300
		Resource utilization rate of incubating	0.35	0.65-0.75	0.8-1.0	0.6-0.8	0-0.6
		Growth rate of income of the incubating enterprise	0.35	0.15-0.25	0.4-1.0	0.15-0.4	0-0.15
Social-profit performance	0.20	Employment growth rate	0.30	0.35-0.45	0.4-1.0	0.15-0.4	0-0.15
		Industrial value-added rate of incubating enterprises	0.30	0.08-0.12	0.15-1.0	0.05-0.15	0-0.05
		Lifting force of soft environment of incubating enterprises	0.20	0.45-0.55	0.6-1.0	0.3-0.6	0-0.3
		Lifting force of hard environment of incubating enterprises	0.20	0.3-0.4	0.6-1.0	0.3-0.6	0-0.3

Based on the extension distance formula, we can get the extension distance between each evaluation indicator and management evaluation grade, as is shown in Table 3.

Table 3 Extension distance of management performance evaluation

Indicator layer	**Extension distance**			
	ρ_0^p	ρ_{pI}	ρ_{pII}	ρ_{pIII}
Percentage of success of incubating enterprises	-0.25	0.05	-0.05	0.15
Number of incubating enterprises	-17	-3	3	18
Incubating profit	-0.15	-0.05	0.05	0.15
Percentage of survival of incubating enterprises	-0.35	0.15	-0.05	0.05
Scientific achievement	-28	8	-4	4
Technical transformationability	-0.6	0.15	0	0
Training and learning ability	-0.2	0	0	0.2
Number of cooperation projects of education combined with research and products	-18	3	-2	2
Cost of incubating	-220	30	-30	40
Resource utilization rate of incubating	-0.3	0.1	-0.1	0.1
Growth rate of income of the incubating enterprise	-0.8	0.2	-0.05	0.05
Employment growth rate	-0.6	0	0	0.25
Industrial value-added rate of incubating enterprises	-0.9	0	-0.05	0.05
Lifting force of soft environment of incubating enterprises	-0.5	0.1	-0.1	0.2
Lifting force of hard environment of incubating enterprises	-0.65	0.15	0	0

Therefore, we can get the extension correlation function between each evaluation indicator and management performance grade, as is shown in Table 4.

Table 4 Extension correlation function of management performance evaluation

Indicator layer	Extension correlation function		
	K_{pI}	K_{II}^{p}	K_{III}^{p}
Percentage of success of incubating enterprises	-0.167	0.250	-0.375
Number of incubating enterprises	0.150	-0.150	-0.514
Incubating profit	0.200	-0.250	-0.500
Percentage of survival of incubating enterprises	-0.300	0.250	-0.125
Scientific achievement	-0.222	0.333	-0.125
Technical transformationability	-0.200	0	0
Training and learning ability	0	0	-0.500
Number of cooperation projects of education combined with research and products	-0.143	0.400	-0.100
Cost of incubating	-0.120	0.429	-0.154
Resource utilization rate of incubating	-0.250	0.500	-0.250
Growth rate of income of the incubating enterprise	-0.200	0.200	-0.059
Employment growth rate	0	0	-0.294
Industrial value-added rate of incubating enterprises	0	0.500	-0.053
Lifting force of soft environment of incubating enterprises	-0.167	0.333	-0.286
Lifting force of hard environment of incubating enterprises	-0.188	0	0

According to the algorithm provided by this paper, we can get the comprehensive extension membership degree sequence between management performance and management performance grade, namely, $EMD=(EMD_{I}^{p}, EMD_{II}^{p}, EMD_{III}^{p})=(-0.107, 0.186, -0.222)$.

We can see $EMD_{max}=EMD_{II}^{p}$, which means that the management performance falls into grade II. It is in line with the real situation.

5. CONCLUSION

This paper proposes a management evaluation model of science & technology enterprise incubator based on extension membership degree, aiming at solving problems presented in management performance. It constructs extension distance and extension side-distance of evaluation indicators and get corresponding extension correlation function and extension membership degree. The membership of the management performance is available based on extension membership degree. Empirical study is in line with real situation, which means that the model proposed by this paper can provide policy support to the management of science & technology enterprise incubator.

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