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Constitution analysis and comprehensive evaluation to the value of enterprises' appropriate technology

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ABSTRACT

Appropriate technology is an important part of core competitiveness of enterprises, and its value is diverse and comprehensive. It is of important and strategic significance for an enterprise, a trade and a nation to understand and evaluate the value of appropriate technology correctly in the hope of realizing its sustainable development. On the basis of a large amount of domestic and foreign literature survey, case study and expert consultation, the essay analyzes systematically the connotation and composition of the enterprises' appropriate technology value, and proposes and constitutes preliminarily its corresponding evaluation index system, and also clarifies its comprehensive evaluation model and method from the perspective of the symbiotic relationship of science & technology-economy-society-human-nature. The essay thinks the appropriate technology value of enterprises is composed of the value of science & technology, economy, society, human and ecology, and embodies the sustainable and symbiotic relationship between appropriate technology and its environmental system. Its evaluation in essence is multi-object, multi-factor, multi-layer, fuzzy and comprehensive, of which the key is to constitute rationally an evaluation index system and to select a suitable evaluation method. The constitution of evaluation index system should obey a series of basic principles of objectivity, systematization, science, feasibility and guidance, and it is correct and feasible to select the Fuzzy Comprehensive Evaluation (FCE) method which is multi-factor, multi-layer, multi-operator, combined subjective with objective, qualitative with quantitative and expert review with accurate calculation. In the application of FCE method, the reasonable determination of index weight, evaluation model and compound operation operator is the important content to evaluate the value of appropriate technology objectively, comprehensively, scientifically, reasonably and effectively.

KEYWORDS

Appropriate technology value; Constitution analysis; Evaluation index system; Evaluation model; Fuzzy comprehensive evaluation.

INTRODUCTION

Appropriate technology of enterprises is an important part of the core competitiveness, which possess the diverse and comprehensive value[1], and it is of strategic significance for an enterprise, a trade, and a nation to understand and evaluate correctly its value[2].

In general, the evaluation is to determine its related attributes of objects and transfer them into subjective judgment of value according to the definite goal to analyze systematically the evaluated object. There are two basic stages of the evaluation: one is to analyze the evaluation object systematically and to constitute correspondingly its index system under the guidance of the evaluation target; the other is to determine its related attributes by means of the evaluation index system and transfer them into the evaluators' subjective judgment of value. This is a process of the combination of subjective and objective and the transformation from concrete to abstract and vice versa.

So does the evaluation to the value of appropriate technology. The essay analyzes systematically the connotation and composition of the value of appropriate technology, and proposes and constitutes preliminarily its evaluation index system and its corresponding index weight from the perspective of the symbiotic relationship of science & technology –economy-society-human-nature through expert consultation and extensive literature survey at home and abroad. On this basis, the essay clarifies the model and method of the evaluation to appropriate technology value with cases by the effective Fuzzy Comprehensive Evaluation (FCE)[3], in order to evaluate the value of appropriate technology objectively, comprehensively, scientifically and reasonably.

CONNOTATION OF APPROPRIATE TECHNOLOGY AND ITS VALUE

As we know, the theory of appropriate technology was proposed by E.F.Schumacher, a famous British economist in 70's of 20th century, with the purpose to promote the coordinated development of technology, economy and the natural environment[4]. With the advent of sustainable development theory in 80's, the research vision of appropriate technology theory expanded to the whole big system of science & technology-economy-society-human- nature, and its concern focused on the *symbiotic*[5]relationships among the subsystem of interdependence, mutual integration, mutual benefit and sustainable development. The connotation of appropriate technology also has gradually been enriched. At present in fact, appropriate technology is defined as the technology system which is a self organization structure and able to adapt, promote and coordinate mutually with the external environment system of economy, society and nature, and thus obtains the comprehensive benefits at its best[1]. It becomes the medium of harmonious development between man and nature, and the technology selection to support and achieve low carbon economy, circular economy and sustainable development, and it embodies and represents the fundamental requirements and development direction of technology progress[6]. So it is also called symbiotic technology, harmonious technology or sustainable technology[7].

The value of appropriate technology is created and extended continually in the process of mutual adaptation, mutual coordination, mutual promotion and the interaction between appropriate technology and its environmental system of economy, society, nature. It refers to the effect for appropriate technology to support, adapt, promote and coordinate with the environmental system of economy, society, nature and ecology, and it embodies and represents the relationship of compatibility, integration and symbiosis between appropriate technology and its environmental system[8]. In fact, in the process of interaction with its external environment, as a technology system of specific structure and function, appropriate technology, on the one hand, is in the change of optimization or self organization in its internal structure under the influence of external environmental factors or the state; on the other hand, it promotes the rationalization of its external function or the beneficial and reasonable change of external environment system due to self organization in its internal structure. During the interaction of the two aspects with the internal structure optimization and the external function rationalization, the diverse and comprehensive value of appropriate technology is produced, formed, created and extended.

CONSTITUTION ANALYSIS OF APPROPRIATE TECHNOLOGY VALUE

From the interrelationship of science & technology-economy-society-human-nature, appropriate technology possesses the more, the higher and the better comprehensive value compared to the general technology. It is not only cost-effective, compatible with the economy system, and has sustainable value of economy; but also it is more reasonable, coordinated and compatible with the system of science & technology, society, human requirements and nature, and has sustainable value of science & technology, society, human and ecology. In fact, by its certain internal structure of self organization, appropriate technology realizes continuously the compatible, integrated, adaptable and coordinated development with its whole external system such as science & technology, society, human requirements and nature, and it also realizes continuously its development of industrialization, marketing, socialization, humanization and ecologicalization. Thus the diverse and sustainable appropriate technology value is produced, formed, created and extended continuously. In other words, it is the internal structure of self organization of appropriate technology that leads to its rationality of external functions and its creation and extension of diverse, sustainable and comprehensive value.

Specifically, the constitution of appropriate technology value can be further analyzed as follows.

(1) Science & technology value. Science & technology value of appropriate technology refers to the status, effect and significance of appropriate technology in the whole science & technology system, which embodies the compatible and

symbiotic relationship between appropriate technology and the whole science & technology system. If it is consistent, compatible and symbiotic with a series of factors such as the structure, function, value standard, academic criteria and thinking means of the whole science & technology system, and then the appropriate technology will be the technology of self organization, self regulation and self evolution to support the sustainable development of the whole science & technology system. Therefore, appropriate technology is compatible and symbiotic with the whole science & technology system, and has prominent and sustainable value of science and technology.

(2) Economy value. Economy value of appropriate technology refers to the effect and significance of appropriate technology to the economy system, which embodies the compatible and symbiotic relationship between appropriate technology and economy system. If it is mutually adapted and integrated with the local specific conditions of economy in its R & D, test, production and marketing, and then the appropriate technology will extend the production technology chain, form a stronger capacity of production, self purification and self repair, achieve win-win between appropriate technology and economy, and be the economical technology to support the sustainable development of economy system. Therefore, appropriate technology is compatible and symbiotic with economy system, and has prominent and sustainable value of economy.

(3) Society value. Society value of appropriate technology refers to the effect and significance of appropriate technology to the society system, which embodies the compatible and symbiotic relationship between appropriate technology and society system. If it is mutually adapted and integrated with the local specific conditions of society such as politics, system, law and others according to the local conditions, the proper time and the different individual, and then the appropriate technology will achieve win-win between appropriate technology and society, and be the friendly technology to support the sustainable development of society system in its marketing, industrialization and socialization. Therefore, appropriate technology is compatible and symbiotic with society system, and has prominent and sustainable value of society.

(4) Human value. Human value of appropriate technology refers to the effect and significance of appropriate technology to the human requirements, which embodies the compatible and symbiotic relationship between appropriate technology and human requirements system. If it meets and adapts to the requirements of human physiology, psychology and spirit according to the specific conditions, and then the appropriate technology will always follow and obey laws in the evolution of human beings, promote human progress, achieve win-win between appropriate technology and human, and be the humane technology to support the sustainable development of human system. Therefore, appropriate technology is compatible and symbiotic with system of human requirements, and has prominent and sustainable value of human.

(5) Ecology value. Ecology value of appropriate technology refers to the effect and significance of appropriate technology to the ecology system, which embodies the compatible and symbiotic relationship between appropriate technology and ecology system. If it obeys the natural ecology laws of development, provides only industrial products and raw materials without leaving any waste to ecological environment, recycles natural resources and reuses energy during the production, and then the appropriate technology will achieve win-win between appropriate technology and natural system, and be the ecological or green technology to support the sustainable development of natural ecology system.

In a word, appropriate technology can continuously be compatible, integrated and symbiotic with all aspects of environment such as science & technology, economy, society, human and nature, and it possesses the best, diverse, sustainable and comprehensive value in the unity of science & technology, economy, society, human and ecology. Constitution of appropriate technology value is shown in relation formula (1).

$$V_{at}=F(V_{st}, V_e, V_s, V_h, V_n) \quad (1)$$

Where V_{at} represents the value of appropriate technology; V_{st}, V_e, V_s, V_h and V_n, represents respectively the value of science & technology, economy, society, human and nature; F represents the interaction between V_{st}, V_e, V_s, V_h, V_n and V_{at}.

EVALUATION INDEX SHYSTEM OF APPROPRIATE TECHNOLOGY VALUE

The above analysis to the constitution of appropriate technology value lays the foundation of systematic, correct and rational evaluation of appropriate technology value, which in essence is a comprehensive evaluation of multi-object, multi-factor and multi-layer. It is the key to constitute rationally evaluation index system and to select suitable comprehensive evaluation methods.

Evaluation index system refers to an organic whole of the inherent structure which is constituted by different attributes of the value of appropriate technology and their relationship of various factors. The constitution of evaluation index system of appropriate technology value is a process of abstract, generalization and characterization and transforming abstract concepts into the measured carrier or information indicator. This is the combination of subjective and objective, and the transformation from the concrete to abstract, then from abstract to concrete.

Some basic principles should be obeyed to constitute evaluation index system of appropriate technology value in order to evaluate it objectively, comprehensively, scientifically, reasonably and effectively.

(1) Objective principle. Evaluation index system of appropriate technology value should be objective. Index data is based on the actual statistical data, and make full use of the existing resources such as statistical yearbook, science & technology yearbook to ensure its authority, accuracy and objectivity, but avoid its subjectivity and randomness.

(2) Systematic principle. Because appropriate technology value involves various factors of science & technology, economy, society, human requirements and natural ecology environments, the selection of different indexes should not only

be independent and have their own specific evaluation function, but also be interrelated and combined to form a comprehensive evaluation system including the main evaluation contents.

(3) Scientific principle. Every index should have a clear meaning, clear boundary, be measured and calculated with a certain method, and accurately reflect, describe and instruct the standard and state of appropriate technology value.

(4) Concise principle. On the premise of the integrity of evaluation content and the achievement of evaluation goal, the single index should be as concise as possible, so should the constitution of index system. They should be focused, convenient, less and concise.

(5) Feasible principle. Access to relevant information of constituting index system should be convenient and feasible. Every index comes from reliable data sources, and it is better not to select the index without relevant data.

(6) Guiding principle. This principle emphasizes the particularity of evaluation to appropriate technology value. To select different evaluation index system with purpose and target can highlight the attributes of appropriate technology and its value, and reflect and guide the fundamental requirements and development direction of technology progress.

According to the above constitution principle of evaluation index system and systematic analysis to the constitution of appropriate technology value, the essay constitutes preliminarily the evaluation index system of appropriate technology value composed of 27 indexes (see TABLE 1), through a large amount of domestic and foreign literature survey, questionnaire research, consultation of related different experts and particular investigation of the evaluation indexes widely used by the domestic and foreign experts[9][10][11][12]. The evaluation index system can describe and represent comprehensive appropriate technology value, and it can also reflect and embody the sustainable and symbiotic relationship between appropriate technology and its environment system of science & technology, economy, society, human and nature. As space limited, there is no further description of the above specific index meaning of the evaluation index system.

TABLE 1 : Evaluation index system of appropriate technology value

Object	Evaluation factor	Evaluation index
The Value of appropriate technology	Science & technology value (U_1)	Number of patent granted (u_{11}) Nationalization rate of introduced technology (u_{12}) Standardization rate of technology (u_{13}) Transformation rate of technology achievements (u_{14}) Technology correlation or coverage (u_{15})
	Economy value (U_2)	Number of patent licensing (u_{21}) Cost (u_{22}) Benefit (u_{23}) Degree of industrialization (u_{24}) Rate of market share (u_{25})
	Society value (U_3)	Improvement of working condition (u_{31}) Increase of employment rate (u_{32}) Improvement of people's quality of life (u_{33}) Security of public service (u_{34}) Maintenance of national security (u_{35}) International influence (u_{36}) Number of foreign patent application (u_{37})
	Human value (U_4)	Physiological needs of people (u_{41}) Psychological needs of people (u_{42}) Technology beauty (u_{43}) Responsibility of S & T workers (u_{44}) Improvement of S & T awareness (u_{45}) Compatibility of culture (u_{46})
	Ecology value (U_5)	Rational utility of natural resources (u_{51}) Improvement of natural environment (u_{52}) Ability of reduction of natural disasters (u_{53}) Comprehensive contribution of environmental quality (u_{54})

Considering the difficult quantification of some indexes, and the limitation to solicit opinions from the scale and structure of experts, in the essay the constitution of the evaluation index system of the appropriate technology value is preliminary and needs to be further improved to a more perfect one.

COMPREHENSIVE VALUATION METHOD OF APPROPRIATE TECHNOLOGY VALUE

Based on the reasonable constitution of evaluation index system of appropriate technology value, to evaluate appropriate technology value objectively, scientifically, effectively and feasibly should scientifically select and determine

suitable and comprehensive evaluation method by combining theoretical analysis with practical experience, normative research with empirical research and qualitative analysis with quantitative analysis.

Owe to the uncertainty and fuzziness of appropriate technology value, and the difficulty of quantitative evaluation index, its evaluation in essence is multi-object, multi-factor, multi-layer, fuzzy and comprehensive. Therefore, the essay thinks that it is very suitable to select the FCE method to evaluate the appropriate technology value among various evaluation methods. The method bases on fuzzy mathematics, applies the principle of fuzzy relation complex, quantifies factors without clear boundary, unifies the qualitative and quantitative, the subjective and objective, and grade the object's membership status by various factors. It is very suitable to solve the multi-objective, multi-factor, multi-layer, fuzzy and uncertain comprehensive evaluation problem in order to improve science, effectiveness and feasibility of the evaluation of appropriate technology value.

In the following, the essay analyzes and clarifies specifically the general method and process of comprehensive evaluation to appropriate technology value with FCE by practice[11]. To save space, only the relevant calculation results are listed here instead of the calculation steps and formulas, and the example data is replaced by letters without a specific case analysis.

(1) Constitute the evaluation index system, and determine the corresponding evaluation factors set

Based on the evaluation index system, let the evaluation factor set $U=\{U_i\}$ (i=1, 2, …, m), of which, $U_i=\{u_{ij}\}$(j=1, 2, …, n_i) as evaluation factor (1st level index), m as the number of U_i in U, n_i as the number of 2nd level index u_{ij} in U_i.

As far as the evaluation of appropriate technology value is concerned, according to TABLE 1, let the evaluation factor set of appropriate technology value $U=\{U_1, U_2, U_3, U_4, U_5\}$={science & technology value, economy value, society value, human value, ecology value}, of which, $U_1=\{u_{11}, u_{12}, u_{13}, u_{14}, u_{15}\}$, $U_2=\{u_{21}, u_{22}, u_{23}, u_{24}, u_{25}\}$, $U_3=\{u_{31}, u_{32}, u_{33}, u_{34}, u_{35}, u_{36}, u_{37}\}$, $U_4=\{u_{41}, u_{42}, u_{43}, u_{44}, u_{45}, u_{46}\}$, $U_5=\{u_{51}, u_{52}, u_{53}, u_{54}\}$.

(2) Determine the evaluation grade and standard to constitute the comment set

The determination of the evaluation grade and its corresponding standard is the basis of the evaluation of appropriate technology value. Practice shows that the evaluation grade should generally be divided into reasonable 5-7 grades neither too few nor too many. The connotation of the evaluation standard is determined by its division of evaluation grade and then its corresponding comment set $V=\{v_k\}$ (k=1, 2, …, k_{max}) (k_{max} takes 5-7 usually) is constituted, which reflects the different status of appropriate technology value, and the comments are determined by the experts.

A group of 10 experts in different fields rank them by peer review, take k_{max}=7, and constitute its corresponding comment set $V=\{v_k\}=\{v_1, v_2, v_3, v_4, v_5, v_6, v_7\}$={especially high, very high, moderately high, reasonable, moderately low, very low, especially low}.

(3) Determine the evaluation index weight

In order to know the relative relationship of each index in the evaluation index system, it should be essential to determine scientifically and rationally the corresponding evaluation index weight. Index weight refers to the measurement of its effects and importance in the overall evaluation index system, which represents the ability and contribution degree of the evaluation index and is the measurement of subjective and objective unity. The tendency and flexibility of evaluators who applied evaluation index system of appropriate technology value can be demonstrated by weight distribution and determination of each index on purpose, which reflects the specific conditions and special requirements of appropriate technology and embodies technology development strategy from different enterprises. Therefore, the determination of weight is the important stage and soul of the whole evaluation index system of appropriate technology value.

The methods of weight determination include as follows, expert consultation method, rating method, experience the look-up TABLE method, statistical test method, grey correlation method, comprehensive evaluation of inverse problem calculation method, Analytic Hierarchy Process (AHP) and other variants**[13]**. Some of them focus on subjective experience, which is easy to perform, but less objective; while others are strongly objective, but often complex in analysis and calculation. Therefore, it is to select the corresponding method according to the actual situation. Especially, AHP method is widely used nowadays and based on a solid theoretical foundation owe to its unity of subjective and objective.

In the following the essay obtains the evaluation index weight system (W and w_i) by AHP method and 10 invited experts (usually 9-13), details as follows: The weight of each index in U, U_1, U_2, U_3, U_4, U_5 is respectively $W=\{w_1, w_2, w_3, w_4, w_5\}$, $w_1=\{w_{11}, w_{12}, w_{13}, w_{14}, w_{15}\}$, $w_2=\{w_{21}, w_{22}, w_{23}, w_{24}, w_{25}\}$, $w_3=\{w_{31}, w_{32}, w_{33}, w_{34}, w_{35}, w_{36}, w_{37}\}$, $w_4=\{w_{41}, w_{42}, w_{43}, w_{44}, w_{45}, w_{46}\}$, $w_5=\{w_{51}, w_{52}, w_{53}\}$.

(4) Evaluate the single factor to obtain the single factor evaluation matrix

The single factor evaluation, which is undertaken by the peer review of a group of evaluation experts, determines the 2nd level index u_{ij} in each evaluation factor (1st level index) to be evaluated as membership degree r_{ij} in each evaluation grade v_k. A fuzzy evaluation matrix is obtained to each evaluation factor by the single factor evaluation. Generally, there are two ways to determine r_{ij}: one is Experiential Look-up Tables Method; the other is Statistical Method of Peer Review[14]. A group of 10 invited experts rank each index u_{ij} according to the evaluation grade, and then count the agreement rate of the experts, which is a membership degree $r_{ij,k}$ in each index comment set V, and $r_{ij,k}$ indicates the membership degree of index u_{ij} comment v_k, obviously, $\sum_{k=1}^{k_{max}} r_{ij,k}=1$. So the single factor evaluation matrix $R_i=\{r_{ij,k}\}$ composed of comment set of many j single index (the 2nd level index) of U_i is obtained.

As far as the evaluation of appropriate technology value is concerned, the matrix R_1 composed of each 2nd level single index in the factor (1st level index) U_1 is :

$$R_1=\begin{bmatrix} r_{11,1} & r_{11,2} & r_{11,3} & r_{11,4} & r_{11,5} & r_{11,6} & r_{11,7} \\ r_{12,1} & r_{12,2} & r_{12,3} & r_{12,4} & r_{12,5} & r_{12,6} & r_{12,7} \\ r_{13,1} & r_{13,2} & r_{13,3} & r_{13,4} & r_{13,5} & r_{13,6} & r_{13,7} \\ r_{14,1} & r_{14,2} & r_{14,3} & r_{14,4} & r_{14,5} & r_{14,6} & r_{14,7} \\ r_{15,1} & r_{15,2} & r_{15,3} & r_{15,4} & r_{15,5} & r_{15,6} & r_{15,7} \end{bmatrix}$$

The other single factor evaluation matrix R_2, R_3, R_4, R_5 of 1st level index U_2, U_3, U_4, U_5 are obtained with the same method.

(5) Determine the fuzzy comprehensive evaluation model and fuzzy compound operator

When weight W and the single factor evaluation matrix R are known, the fuzzy comprehensive evaluation model obtained by comprehensive evaluation with the fuzzy compound operator $\overset{\cdot}{*}$ and $\overset{+}{*}$ is[15]:

$$WoR=B=(b_1b_2\ldots b_m) \quad \textbf{(2)}$$

Where, $b_j=(w_1 \overset{\cdot}{*} r_{1j}) \overset{+}{*} (w_2 \overset{\cdot}{*} r_{2j}) \overset{+}{*} \ldots (w_n \overset{\cdot}{*} r_{nj})$.

This model is simplified as $M(\overset{\cdot}{*}, \overset{+}{*})$.

In principle, the fuzzy compound operations are infinite, but only five specific models are developed up to now, see TABLE 2.

TABLE 2 : Models of fuzzy compound operations type

Type M	$M(\wedge,\vee)$	$M(\bullet,\vee)$	$M(\bullet,\oplus)$	$M(\wedge,\oplus)$	$M(\bullet^k,\wedge)$
Operation b_j Operator o	$b_j=\max[\min(w_1, r_{1j}), \min(w_2, r_{2j}), \cdots \min(w_n, r_{nj})]$	$b_j=\max[w_1r_{1j}, w_2r_{2j}, \cdots w_nr_{nj}]$	$b_j=\min[1, \sum_{i=1}^{n} w_i r_{ij}]$	$b_j=\min[1, \sum_{i=1}^{n} \min(w_i, r_{ij})]$	$b_j=\min[w_1r_{1j}^1, w_2r_{2j}^2, \cdots w_nr_{nj}^n]$
$\overset{\cdot}{*}$	$\overset{\cdot}{*} \to \wedge$ $\alpha\wedge\beta=\min(\alpha,\beta)$	$\overset{\cdot}{*} \to \bullet$ $\alpha\bullet\beta=\alpha\times\beta$	$\overset{\cdot}{*} \to \bullet$ $\alpha\bullet\beta=\alpha\times\beta$	$\overset{\cdot}{*} \to \wedge$ $\alpha\wedge\beta=\min(\alpha,\beta)$	$\overset{\cdot}{*} \to \bullet^k$ $\alpha \bullet^k \beta = \beta^\alpha$
$\overset{+}{*}$	$\overset{+}{*} \to \vee$ $\alpha\vee\beta=\max(\alpha,\beta)$	$\overset{+}{*} \to \vee$ $\alpha\vee\beta=\max(\alpha,\beta)$	$\overset{+}{*} \to \oplus$ $\alpha\oplus\beta=\min(1,\alpha+\beta)$	$\overset{+}{*} \to \oplus$ $\alpha\oplus\beta=\min(1,\alpha+\beta)$	$\overset{+}{*} \to \wedge$ $\alpha\wedge\beta=\min(\alpha,\beta)$

The different operator o in TABLE 2 has various attributes and characteristics, plays a different role, and embodies the different thought and purpose of comprehensive evaluation in various fuzzy compound operations. Therefore, it is of vital significance to select the operator of fuzzy compound operations in the fuzzy comprehensive evaluation. In general, there are many methods and principles to select the operator of fuzzy compound operations as in TABLE 3.

TABLE 3 : Types and features of operator in fuzzy compound operations

Operator	Features			
	Types	**Weight effects**	**Information R**	**Comprehensive degree**
$M(\wedge,\vee)$	main factors prominent	not obvious	not full	weak
$M(\bullet,\vee)$	Main factors prominent	obvious	not full	weak
$M(\bullet,\oplus)$	Weighted average	obvious	full	strong
$M(\wedge,\oplus)$	Weighted average	not obvious	much full	strong
$M(\bullet^k,\wedge)$	Main factors prominent	obvious	full	weak

(6) Produce results of single factor fuzzy evaluation and fuzzy comprehensive evaluation

The single factor fuzzy evaluation is to evaluate singly each index u_{ij} (2^{nd} level index) in subset U_i. After obtaining the single factor evaluation matrix R_i, together with the weight w_i of index u_{ij}, the results B_i of single factor fuzzy evaluation of U_i is produced by the fuzzy compound operation $B_i=w_i o R_i$.

On the basis of single factor fuzzy evaluation, its higher layer fuzzy comprehensive evaluation is produced further, which takes the results B_i of single factor fuzzy evaluation as the evaluation matrix $R=\{B_i\}$ of higher layer fuzzy comprehensive evaluation, together with the weight W of single evaluation factor U_i, and then the result B of higher layer fuzzy comprehensive evaluation is produced by the fuzzy compound operation B=WoR.

Similarly, multiple layer results of fuzzy comprehensive evaluation are produced, and so on.

As far as the enterprise evaluation of appropriate technology value is concerned, the result B_i of single factor fuzzy evaluation of U_1 is:

$$B_1=w_1 o R_1=[w_{11}, w_{12}, w_{13}, w_{14}, w_{15}]$$

$$o\begin{bmatrix} r_{11,1} & r_{11,2} & r_{11,3} & r_{11,4} & r_{11,5} & r_{11,6} & r_{11,7} \\ r_{12,1} & r_{12,2} & r_{12,3} & r_{12,4} & r_{12,5} & r_{12,6} & r_{12,7} \\ r_{13,1} & r_{13,2} & r_{13,3} & r_{13,4} & r_{13,5} & r_{13,6} & r_{13,7} \\ r_{14,1} & r_{14,2} & r_{14,3} & r_{14,4} & r_{14,5} & r_{14,6} & r_{14,7} \\ r_{15,1} & r_{15,2} & r_{15,3} & r_{15,4} & r_{15,5} & r_{15,6} & r_{15,7} \end{bmatrix}$$

And so is the other four results B_2, B_3, B_4, B_5 of single factor fuzzy evaluation of single evaluation factor U_2, U_3, U_4, U_5.

On the basis of the results above, higher layer fuzzy comprehensive evaluation of appropriate technology value is produced. The evaluation matrix $R=(B_1, B_2, B_3, B_4, B_5)^T$ of a higher layer U is constituted by the results B_i of single factor fuzzy evaluation of U_i. Finally the fuzzy comprehensive evaluation result B of enterprises' appropriate technology value U produced by the fuzzy compound operation is:

$$B=WoR=[w_1, w_2, w_3, w_4, w_5]$$

$$o[B_1, B_2, B_3, B_4, B_5]^T.$$

CONCLUSIONS

Enterprises' appropriate technology value is a diverse value system of science & technology value, economy value, society value, human value and ecology value. Its evaluation in essence is a multi-object, multi-factor, multi-layer, fuzzy and comprehensive evaluation, of which the key is to constitute rationally evaluation index system and to select suitable comprehensive evaluation methods including the rational distribution of index weight and the selection of fuzzy comprehensive evaluation models and fuzzy compound operations. The above analysis proves that the multi-factor, multi-layer and multi-operator method of FCE combines subjective with objective, qualitative with quantitative and expert review with accurate calculation, and provides a more systematic, comprehensive, scientific and practical method for the evaluation of enterprises' appropriate technology value.

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REFERENCES

[1] Pan Peng; The Enlightenment of Appropriate Technological Theory. Wuhan: Wuhan University of Technology (Social Science Edition), 28-32 **(June, 2003)**.

[2] Mike Morris; The Early Years of the National Center for Appropriate Technology. Social Studies of Science, 19-24 **(May-2009)**.

[3] Peizhuang Wang; Introduction to Fuzzy Mathematics, Beijing: Practice and Understanding of Mathematics, 2-3 **(1980)**.

[4] E.F. Schumacher; Small is beautiful[M], Beijing: the Commercial Press, 26-27 **(1985)**.

[5] L.Margulis , Fester (ed.); Symbiosis as a Source of Evolutionary Innovation[M], MIT Press, 3-5 **(1991)**.

[6] C.John, V.Pezzey; Sustainable Development Concepts: An Economic Analysis[M], The World Bank, Washington D.C, **(2002)**.

[7] Zhenfeng Su; Harmonious Technology-Constructing Technology in Harmonious Society, Xian: Journal of Electronic Science and Technology University (Social Science Edition), **1**, **(2009).**

[8] Chonglin Yang, Zhijin Xu; Accounting of Sustainable National Wealth: Progress, Problems and Solution, Beijing: Journal of Capital Normal University, **6**, **(2012)**.
[9] C.Vesna, Z.Jo, R.Knez; Why and how to evaluate the creditworthiness of SMEs' business partners, International Small Business Journal, **23(2)**, 143 **(2005)**.
[10] Bin Wang, Qingmei Tan; Evaluation Index System of Industry Innovation Platform and its Weight Setting, Beijing: Science of Science and Management of Science and Technology, **12**, **(2013)**.
[11] Zhijin Xu; Symbiotic Innovation of Appropriate Technology to Support Circular Economy and Harmonious Society, Beijing: China soft science, **4, (2006)**.
[12] Jianlin Zhu; Improvement of Evaluation Index System of Input and Output for Enterprises' Technology Innovation, Statistical Science and Practice, **4, (2013)**.
[13] Hong Jiang, Ziyou Gao; A Fuzzy Comprehensive Evaluation Model of the Level of City Public Transportation Development Based on AHP, Rizhao; Journal of Qufu Normal University, **1**, **(2012)**.
[14] Xiaojing Hui; Wine Classification and Evaluation on Fuzzy Mathematics Method, Beijing: Understanding and Practice of Mathematics, **16**, **(2013)**.
[15] Jun Wang. Xiaoyan Wang; Research of Risk Management of BOT Project-Based on Fuzzy Comprehensive Evaluation Model, Beijing: Value Engineering, **3**, **(2013)**.