Study on Development of Cultural and Technological Integration Based on AHP- Fuzzy Comprehensive Evaluation

Chenglin Zheng, Wei Jiang, Mei Liu, Longfei Zhang, and Shaoda Bing

***Abstract*—This paper firstly defines the connotation of cultural and technological Integration and analyzes its main hierarchies. Based on the principle of constructing index system , this study forms the evaluation index system of the development level of cultural and technological Integration, including readiness degree, maturity degree, and contribution degree. Then combines analytical hierarchy process with fuzzy comprehensive evaluation process in the evaluation model and proves its validity through empirical research.**

***Index Terms*—AHP-fuzzy comprehensive evaluation, cultural and technological integration, evaluation index system.**

I. Introduction

With keeping moving forward of political, economic and social construction of China since reform and opening-up, the role culture plays is getting more and more important, and strategic power of cultural construction is constantly advancing. Since establishing "Cultural Power" as national strategy in December, 2012, cultural construction and development has entered a new course, cultural innovation elements gathering together on the platform of national strategies, the combination of cultural and technological Integration and cultural system innovation turns out an important strategic support for national cultural prosperity and development [1].

After ten years' exploration and accumulation of experience on culture system innovation, integrating innovation of Cultural and technological gradually becomes the main technology roadmap of culture innovation in our country. With the issue of <Outline of National Culture and Technology Innovation Project> and the establishment of the first batch of national demonstration base of cultural and technological integration, the integration of cultural and technological has comprehensively started [2]. All culture management departments and culture corporations have been joining in the trend of integration of cultural and technological. A large number of parks, enterprises, projects and products are spring up. However, nobody can give answers to how they develops and what the effect is which matter crucial problems such as master of present situation and plan for the future development. Therefore, it is vital to make a complete systematic research into it and a scientific evaluation on its development level.

Manuscript received August 1, 2013; revised November 19, 2013.

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II. Connotations and Hierarchies of Cultural and Technological Integration

A. Connotations of Cultural and Technological Integration

As one of the culture product factors, scientific technology play an important role in culture construction as its drive-support-promote function, and becomes the decisive power and primitive drive force of culture development. Every great progress of scientific technology brings forth revolutionary change to culture's development style, transmission mode and display form. And the integration of cultural and technological will engender profound influence on the entire society [3].

As to macro scope, the integration of cultural and technological means dynamic integration of all kinds of culture elements, content, forms, services, combined with scientific technology principles, theories, approaches, so as to promote culture products' value and quality, form new content, forms, functions and services, and satisfy people's demand for spirit and material culture.

As to neutral and micro scope, the integration of cultural and technological aims to make full use of existing resources and develop new target products under the guidance of new thoughts and methods. It should accord to characteristics of different culture fields, abide by regular pattern of cultural and technological innovation, and exactly understand the need of the market.

On the whole, integration of cultural and technological aims to create new culture production, transmission and consumption forms, and enhancing the vitality of culture development by catering to the need of culture development and using technology principles, methods and approaches. It can also foster new culture industry groups and culture consumption crowds, and create greater value for society by updating the whole culture industry.

B. Hierarchies of Cultural and Technological Integration

The integration of cultural and technological is not as simple as mix of milk and water. It crosses very different fields and includes very different thoughts. It is a gradual process of different forms, scopes and levels. According to differences between evaluation objects, this paper divides the evaluation on integration into three hierarchies. They are enterprises hierarchy, industry hierarchy and area hierarchy.

DOI: 10.7763/IJIEE.2014.V4.405

- **Enterprise hierarchy**: the evaluation objects are culture-technology enterprises, which are the subject, the frontline, the foothold of the integration of culture and technology, and are the micro scope of the evaluation.
- **Industry hierarchy**: the evaluation objects include many kinds of culture industries such as publish, film and television production, print and reprography, ads exhibition, entertainment, culture creation, animation and so on. It is the noumenon of the integration and the neutral scope of the evaluation.
- **Area hierarchy**: the evaluation objects mainly include demonstration base, culture Industry Park and research base. It is the development environment and carrier of the integration, and the macro scope of the evaluation.

III. Construction of Evaluation Index System

A. Principles of Construction

Considering the current situation and the main features of cultural and technological integration in China, the specific evaluation principles, which should be followed when constructing the evaluation system, are listed as the followings.

- **Science-oriented Principle**: the design of index system must base on science, and objectively reflect inner regular pattern of cultural and technological integration. In order to obtain a scientific and objective evaluation result, thorough survey and research using both quantitative and qualitative indices are also necessary.
- **Comparison-oriented Principle**: since index system can comprehensively evaluate the integration conditions of many enterprises, the design must take differences between every single enterprise into consideration. As to selecting specific indices, we should think more of comprehensive indices with general characters, and try best to keep the statistic scope the same to ensure the indices' comparability.
- **Combination of Qualitative and Quantitative Principle**: combination of quantitative and qualitative indices can not only make the evaluation objective and easy to be handled by math model, but also make up the disadvantages of quantitative indices and shortcomings of the data itself.
- **Practicality-oriented Principle**: besides satisfying the basic requirements of evaluation and offering information for decision-making, we should also try to reduce the number of indices and highlight the key indices, which can make the system simple and clear. What's more, to make the system feasible, it is necessary to ensure the easy collection of the indices data, and accordance with the current statistics method.
- **Comparatively Independence Principle**: since the connotation and denotation of cultural and technological integration is abundant, there are many overlaps between indices; we should try to select comparatively independent indices, especially so that the evaluation can be precise and scientific.
- **System-oriented Principle**: the evaluation system should be able to reflect the evaluation objects' conditions entirely and comprehensively. The indices of the system should have logic relationship, and not only include the main features of integration but also reflect its current conditions and development. In a word, the system should not be a pile of indices but an organic whole.

B. Determination of Evaluation Objects

As the micro scope of cultural and technological integration, enterprises should innovatively utilize new knowledge of culture and technology to improve techniques and create new products and services by keeping to directions of market and guidance of new thoughts. All these give enterprises chances to not only make profit but also bring about cultural and social benefit at the same time. Its development level of integration is the basis of culture industry and culture areas. It is also a significant reference and worth a research. So it is necessary to structure an evaluation system of integration that takes enterprises as the objects.

Culture industry and area are the other two hierarchies of cultural and technological integration. Though their integration level is directly influenced by enterprise hierarchy, their development features and influential factors are very different. Consequently, evaluation on the industry and area hierarchy cannot be seen as analogous as the enterprise hierarchy. The research on these two hierarchies' evaluation will not be introduced in this paper.

C. Evaluation Index System of Development Level of Cultural and Technological Integration

With the goal of fully reflecting the development level of the integration, by the principle of indices selecting, the index system is constructed based on the literature review, investigation and research, and expert interview, etc. The index system consists of 3 secondary indices including readiness degree, maturity degree, and contribution degree, with 8 tertiary indices and 32 quartus indices in total, as shown in Table I.

IV. The AHP-Fuzzy Comprehensive Evaluation Model

A. Establish AHP-Fuzzy Evaluation Method

A procedure of using AHP to determine weight: [4]

Firstly, Establishing AHP model:

On the basis of in-depth investigation, the factors included in the issue will be divided into different layers, such as goals layer, guidelines layer, indices layer and so on, building hierarchical model.

Secondly, construct judgment matrix:

This kind of matrix indicates the degree of bilateral importance between the relative factors in this layer contrasting some factor in the former layer. Assume that a_k in layer *A* is linked to $B_1, B_2 \cdots B_n$ in the next layer *B*, and we can construct the following judgment matrix *B*:

$$\begin{bmatrix} a_k & B_1 & \cdots & B_n \\ B_1 & b_{11} & \cdots & b_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ B_n & b_{n1} & \cdots & b_{nn} \end{bmatrix}$$

TABLE I: EVALUATION INDEX SYSTEM OF DEVELOPMENT LEVEL OF CULTURAL AND TECHNOLOGICAL INTEGRATION (ENTERPRISES HIERARCHY)

Primary Aim	Aims	Principles	Indices	
The Development of Cultural and technological Integration (A)	Readiness (B1)	Macro Environment (C11)	Regional Strategic design	(D111)
			Policy tools configuration	(D112)
			Management systems and mechanisms	(D113)
			Construction of public platform	(D114)
		Enterprise Foundation (C12)	Performance and reputation	(D121)
			Strategy plan for the enterprise	(D122)
			Management of intellectual property	(D123)
			Innovation of culture construction	(D124)
			The intensity of innovation input	(D125)
	Maturity (B2)	Front-end Driver (C21)	Construction of research and development institutions	(D211)
			Achievements of Intellectual property right	(D212)
			Standard construction	(D213)
		Middle-end Driver （C22）	Input intensity of second innovation	(D221)
			Abilities of commercialization of research findings	(D222)
			Combination of enterprises, universities and research institutes	(D223)
		Back-end Driver（C23）	Market competition ability	(D231)
			Innovation of business model	(D232)
			International competitive ability	(D233)
	Contribution (B3)	Economic Benefits （C31）	Strength of innovation gains	(D311)
			Rate of cost reduction	(D312)
			Overall labor productivity	(D313)
		Cultural Benefits （C32）	Enriching cultural production factors	(D321)
			Promoting effects of culture storage	(D322)
			Enhancing culture communication ability	(D323)
			Improving the quality of cultural structure	(D324)
			Transforming the mode of cultural experience	(D325)
			Activating the culture original innovation	(D326)
			Giving rise to new culture formats	(D327)
			Expanding cultural consumption demand	(D328)
		Social Benefits（C33）	Social responsibility	(D331)
			Promoting cultural rights and interests of citizens	(D332)
			Leading the social fashion	(D333)

Among them, b_{ij} shows the factor B_i's relative importance to B_j when compared to the previous layer's factor a_k. Judgment matrix B has the following characteristics: $b_{ii}=1\ b_{ij}=1/b_{ji}$, $b_{ik}b_{kj}=b_{ij}(i,j,k=1,2,\cdots n)$. b_{ij}' s value can be figured by reciprocals of 1 to 9 and these figures were called Scaling judgment matrix (as shown in Table II).

TABLE II: JUDGMENT MATRIX SCALE AND ITS DEFINITION

Scale	Definition	Scale	Definition
1	equal importance	2	between 1 and 3
3	slight importance	4	between 3 and 5
5	obviouse importance	6	between 5 and 7
7	intense importance	8	between 7 and 9
9	absolute importance		

Scaling judgment matrix has been proved by T. L. Saaty after a large number of simulation experiments, with the other 26 kinds of scaling method of comparison, 1 to 9 scales will quantify the thinking judgment more effectively. Listed in the tables of 1~9 scale, the numbers shown in the scales indicate the relative importance of the two elements of the hierarchy, and based on which judgment matrix can be constructed [5].

Thirdly, Calculation of the relative weight indices:

Assume calculation steps of judgment matrix $B=(b_{ij})_{n\times m}$, root methods are:

Step 1: Calculate the product for all elements of the plot line.

$$M_i=\prod_{j=1}^{n} b_{ij},(i=1,2,\cdots n) \tag{1}$$

Step 2: Calculate the n-th root of M_i.

$$a_i=\sqrt[n]{M_i},(i=1,2,\cdots n) \tag{2}$$

Step 3: On a vector $a=(a_1,a_2,\cdots a_n)^T$ for normalized treatment.

$$w_i=a_i/\sum_{i=1}^{n} a_k,(i=1,2,\cdots n) \tag{3}$$

Make and get the maximum eigenvalue corresponding eigenvector: $W=(w_1,w_2,\cdots w_n)^T$.

Step 4: Calculate B for the largest eigenvalue.

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{\left(BW_i\right)}{w_i} \tag{4}$$

Fourthly, carry a consistency test:

Step 1: Indicators of consistency CI.

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{5}$$

Step 2: from an average of random consistency indicators in search of the average test of consistency random indicators RI (as shown in Table Ⅲ) [6].

TABLE III: AVERAGE RANDOM CONSISTENCY INDICES RI

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Calculation of the relative ratio of consistency.

$$CR=\frac{CI}{RI} \tag{6}$$

Use CR rate with consistency test to judge the matrix consistency, the smaller the CR is, the better consistency of judgment matrix is. It is generally believed that when $CR\leqslant 0.1$, the judgment is satisfied with the consistency of matrix standard and the result from chromatography-sort is acceptable; Otherwise, it needs to amend the judgment matrix until test passes [7].

B. Fuzzy Comprehensive Evaluation

- **Establishing fuzzy comprehensive evaluation matrix:** Assume that factors or indicators set for the $U=\{u_1,u_2,\cdots,u_n\}$, factors review set for $V=\{v_1,v_2,\cdots v_m\}$, review set $v_j(j=1,2,\cdots,m)$ means evaluation grades for the factors or indicators. The fuzzy evaluation of the factors is a fuzzy subset of the *V*. Assume that the i_{th} element of the single factor fuzzy evaluation is: $R_i=\{r_{i1},r_{i2},\cdots r_{im}\}(i=1,2,\cdots n)$, in which r_{ij} indicates the the membership from i_{th} factor to j_{th} factor. N-fuzzy vector $R_1, R_2, \ldots R_N$ constitute a fuzzy relationship from *U* to *V*, then the fuzzy comprehensive evaluation matrix is:

$$R=(r_{ij})_{m\times n}=\begin{bmatrix}R_1\\R_2\\R_3\\\vdots\\R_n\end{bmatrix}=\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1m}\\r_{21}&r_{22}&\cdots&r_{2m}\\r_{31}&r_{32}&\cdots&r_{3m}\\\vdots&\vdots&\ddots&\vdots\\r_{n1}&r_{n2}&\cdots&r_{nm}\end{bmatrix} \tag{7}$$

- **Single-factor analysis:** Asume that the factors set $U=\{u_1,u_2,\cdots,u_n\}$, correspondingly its weight vector is $W_i=(w_{i1},w_{i2},\cdots,w_{in})$, the membership w_{ik} means single-factor weight in the evaluation of the various factors.Given the W_i and R_i,we can conclude the single factor evaluation Vector:

$$B_i=W_i\bullet R_i=(b_{i1},b_{i2},\cdots b_{im}),(i=1,2,\cdots k) \tag{8}$$

- **Comprehensive Evaluation on factors**: Assume that the weight vector for each subset is $W=(w_1,w_2,\cdots,w_k)$, the comprehensive evaluation matrix is $R=(B_1,B_2,\cdots B_k)^T=(b_{ij})_{k\times m}$. Therefore, comprehensive evaluation vector is

$$A=W\bullet R=(b_1,b_2,\cdots b_m). \tag{9}$$

According to the maximum membership principle, if the max b_i is found, then level of what is being evaluated can be known. Consideration of the comprehensive evaluation vector contain abundant information ,we can make full use of it by the means of giving comments set *V* a relevant specific scores, then use $S=A\times V^T$ to get an absolute value, which isn't influenced by the evaluation object' objects set, so it can be used to compare ,rank and select [8].

V. EVALUATION AND ANALYSIS OF AHP-FUZZY COMPREHENSIVE EVALUATION MODEL

Use AHP- fuzzy comprehensive evaluation method to evaluate, in accordance with index system established to judge. In the form of experts' points, we can confirm weights for first, second and third indicators and fuzzy relationship matrix [9].

Indicated by the relevant experts, we construct a judgment matrix at all levels' indicators, just take "Macro Environment" for example (as shown in Table Ⅳ):

TABLE IV: JUDGMENT MATRIX AND WEIGHT OF MACRO ENVIRONMENT

C11	D111	D112	D113	D114	Weight
D111	1	1/3	2	1/2	0.1601
D112	3	1	4	2	0.4673
D113	1/2	1/4	1	1/3	0.0954
D114	2	1/2	3	1	0.2772

A. Calculate Weight of Indicators at All Levels

First level weight vector:

$$WA=(0.16\ \ 0.30\ \ 0.54)$$

Second level weight vectors:

$$WB_1=(0.50\ \ 0.50)$$
$$WB_2`=(0.54\ \ \ 0.30\ \ \ 0.16)$$
$$WB_3=(0.16\ \ 0.54\ \ 0.30)$$

Third level weight vectors:

$$WC_{11}=(0.16\ \ 0.47\ \ 0.10\ \ 0.28)$$
$$WC_{12}=(0.09\ \ 0.14\ \ 0.23\ \ 0.06\ \ 0.49)$$
$$WC_{21}=(0.16\ \ 0.54\ \ 0.30)$$
$$WC_{22}=(0.14\ \ 0.63\ \ 0.24)$$
$$WC_{23}=(0.64\ \ 0.26\ \ 0.10)$$
$$WC_{31}=(0.63\ \ 0.24\ \ 0.14)$$
$$WC_{32}=(0.17\ \ 0.12\ \ 0.26\ \ 0.08\ \ 0.26\ \ 0.05\ \ 0.03\ \ 0.02)$$
$$WC_{33}=(0.54\ \ 0.30\ \ 0.16)$$

B. Conduct Fuzzy Comprehensive Evaluation

Step 1: Determine the evaluation index set.

$A=\{B_1, B_2, B_3\}$, respectively representing three aspects including readiness degree, maturity degree, and contribution degree, Identify a subset evaluation indicator

for: $B_i=\{C_{ij}\}(i=1, 2, 3, j=1, 2, 3)$, and $C_{ij}=\{D_{ijk}\}(i=1, 2, 3\ j=1, 2, 3\ k=1, 2, 3, 4, 5, 6, 7, 8)$.

Step 2: Identify the grading of reviews and corresponding standards.

Determine reviews Set as,

$$V=\{V_1,V_2,V_3,V_4,V_5\}=\{\text{best, better, average, poor, worse}\}$$

Step 3: Establish the single factor fuzzy comprehensive evaluation matrix.

Chose an enterprise *X* as an evaluation object, employ 20 experts to assess its level of integration development. According to their understanding and experience, experts attach different points to the separate indicator from different grades of indicators. Due to indicators of being fuzzy, each expert's times of grading can be integrated to get membership belonging to certain reviews grade, based on which single-factor fuzzy comprehensive evaluation matrix can be established. Calculation results are as below:

$$RC_{11}=\begin{bmatrix}0.2 & 0.5 & 0.3 & 0 & 0\\ 0.1 & 0.2 & 0.5 & 0.2 & 0\\ 0.1 & 0.1 & 0.2 & 0.4 & 0.2\\ 0.2 & 0.2 & 0.4 & 0.2 & 0\end{bmatrix}$$

$$RC_{12}=\begin{bmatrix}0.2 & 0.3 & 0.4 & 0.1 & 0\\ 0.1 & 0.4 & 0.4 & 0.1 & 0\\ 0.2 & 0.3 & 0.3 & 0.2 & 0\\ 0.1 & 0.4 & 0.1 & 0.2 & 0.2\\ 0.2 & 0.3 & 0.3 & 0.1 & 0.1\end{bmatrix}$$

Step 4: Evaluation of a single factor.

$$C_{11}=WC_{11}\times RC_{11}=\begin{bmatrix}0.14 & 0.24 & 0.41 & 0.19 & 0.02\end{bmatrix}$$

$$C_{12}=WC_{12}\times RC_{12}=\begin{bmatrix}0.18 & 0.32 & 0.31 & 0.13 & 0.06\end{bmatrix}$$

Step 5: Secondary comprehensive indicators evaluation.

$$RB_1=\begin{bmatrix}C_{11}\\ C_{12}\end{bmatrix}=\begin{bmatrix}0.14 & 0.24 & 0.41 & 0.19 & 0.02\\ 0.18 & 0.32 & 0.31 & 0.13 & 0.06\end{bmatrix}$$

$$B_1=WB_1\times RB_1=\begin{bmatrix}0.16 & 0.28 & 0.36 & 0.16 & 0.04\end{bmatrix}$$

Step 6: As the same process, calculate other secondary comprehensive evaluation.

$$RB_2=\begin{bmatrix}C_{21}\\ C_{22}\\ C_{23}\end{bmatrix}=\begin{bmatrix}0.05 & 0.17 & 0.26 & 0.33 & 0.19\\ 0.25 & 0.19 & 0.26 & 0.21 & 0.09\\ 0.29 & 0.17 & 0.28 & 0.19 & 0.06\end{bmatrix}$$

$$B_2=WB_2\times RB_2=\begin{bmatrix}0.15 & 0.18 & 0.26 & 0.27 & 0.14\end{bmatrix}$$

$$RB_3=\begin{bmatrix}C_{31}\\ C_{32}\\ C_{33}\end{bmatrix}=\begin{bmatrix}0.15 & 0.48 & 0.23 & 0.14 & 0.00\\ 0.24 & 0.21 & 0.27 & 0.20 & 0.09\\ 0.22 & 0.27 & 0.30 & 0.15 & 0.06\end{bmatrix}$$

$$B_3=WB_3\times RB_3=\begin{bmatrix}0.22 & 0.27 & 0.30 & 0.15 & 0.06\end{bmatrix}$$

Step 7: Three-level comprehensive indicators evaluation.

$$RA=\begin{bmatrix}B_1\\ B_2\\ B_3\end{bmatrix}=\begin{bmatrix}0.16 & 0.28 & 0.36 & 0.16 & 0.04\\ 0.15 & 0.18 & 0.26 & 0.27 & 0.14\\ 0.22 & 0.27 & 0.30 & 0.15 & 0.06\end{bmatrix}$$

$$A=WA\times RA=\begin{bmatrix}0.19 & 0.24 & 0.30 & 0.19 & 0.08\end{bmatrix}$$

Step 8: Calculate the final score.

Asume that review set corresponding matrix is

$$V=(\text{best better average pool worse})$$

$$=(90\quad 80\quad 70\quad 60\quad 50)$$

Step 9: Final score.

$$S=A\times V^T$$

$$=\begin{bmatrix}0.19 & 0.24 & 0.30 & 0.19 & 0.08\end{bmatrix}\times\begin{bmatrix}90\\ 80\\ 70\\ 60\\ 50\end{bmatrix}=72.77$$

The final score shows that the cultural and technological integration development of enterprise *X* is between average and better, according to the review sets.

VI. Conclusion

This paper puts forward a complete 'evaluation index system of the development level of cultural and technological integration' on the basis of thorough research and analysis. Considering the characteristics of evaluation objects and selected indices, this paper combines analytical hierarchy process with fuzzy comprehensive evaluation process in the evaluation model and proves its validation through examples.

The aim of evaluation is to accurately understand current situations of integration of cultural and technological development level and provide information for enacting relative policies, measures and plans. In addition, through evaluation and comparison, evaluation objects can understand their own development level, potentiality, advantages and disadvantages, which will arouse their enthusiasm on integration of culture and technology and give them chances to learn advanced experience to grow quickly and develop by stride.

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