Proceeding of the 11th World Congress on Intelligent Control and Automation
Shenyang, China, June 29 - July 4 2014

AHP Fuzzy Comprehensive Method of Supplier Evaluation in Social Manufacturing Mode

Gang Xiong IEEE Senior Member
Cloud Computing Center，Chinese Academy of Sciences,
Songshan Lake, Dongguan, China.523808

Yaran Chen
Beijing Engineering Research Center of Intelligent Systems and Technology
Institute of Automation, Chinese Academy of Sciences,
Beijing, China. 100190

Xiuqin Shang, Xiwei Liu
Dongguan Research Institute of CASIA
Cloud Computing Center, Chinese Academy of Sciences
Dongguan, China

Timo R. Nyberg
School of Science
Aalto University
Espoo, Finland

***Abstract*—With the development of rapid prototype 3D printing technology, social manufacturing era is coming too. The paper mainly introduces the framework of social manufacturing, which is able to perceive and influence the customers and satisfy the demand of mass customization. Under the framework, an evaluation system for garment enterprises is proposed to select the best supplier based on AHP and fuzzy comprehensive method. This method considers both qualitative and quantitative factors simultaneously. The system's validity and practicability have been verified in the Dongguan garment enterprises.**

Keywords—social manufacturing; supplier evaluation; AHP;

I. Introduction

With the rapid development of computers and Internet communication technologies, the emergence of many new technologies which are changing the basic rules of competition has brought new challenges to the traditional mode of manufacturing. So companies need a new mode of manufacturing under new market environment.

In 1970, Alvin Toffler first proposed the idea of completely new production model with mass customization in the book 《Future Shock》, which provides customers with products and services to the specific needs in the cost and time similar to standardization and mass production. In 1987, Start Davis called this production as "Mass Customization" for the first time, namely mass customization (MC) in 《Future Perfect》book. In 1993, in the book 《Mass Customization: a new frontier in business competition》B•Joseph Pine II pointed out that for mass customization the core is the variety of products and the rapid increase of the diversification instead of the increase of the cost correspondingly, and the scope is mass production of customized products[1]. The major advantage is to provide a strategic advantage and economic value.

Wang Feiyue, Professor of Chinese Academy of Sciences puts forward the social manufacturing model firstly which makes enterprises transform from traditional industries to intelligent ones which is able to perceive and influence the customers and satisfy the demand of mass customization, its core is to link up social needs and social manufacturing actively, promptly and organically, so as to realize the conversion between demand and supply effectively.

II. Social manufacturing model

A. social manufacturing model

Modern society is an era of personalized product and service, mass customization is the main characteristic of social manufacturing. Under the concept of social manufacturing, survival environment of traditional enterprise has changed. They must take the initiative to perceive customer needs and affect them to do mass customization, to organically link up social needs and social manufacturing promptly, so as to effectively realize conversion between demand and supply [2].

Social manufacturing is to combine the related fields of social search, social computing and social manufacturing together, to seamlessly link up the network of social manufacturing composed of Internet, Internet of Things and 3d printer, thus making social people fully participate in the whole manufacturing process of the product life by outsourcing, facilitating personalized, real-time and socialized production and consumption patterns, eventually resulting in a new industrial revolution [3].

This paper introduces a social cloud system, which is based on consumers' active participation and network information technology, and composed of 3 d technology, personalized design and the combination of cloud business sales and intelligence logistics, shown in Figure 1.

B. the characteristics of the supply chain and suppliers

Social manufacturing model requires enterprises to response to customized demand of customer quickly and low-costly, and to coordinately integrate internal resources and external resources effectively in order to maximize economic benefits. To establish a customer-centric supply chain

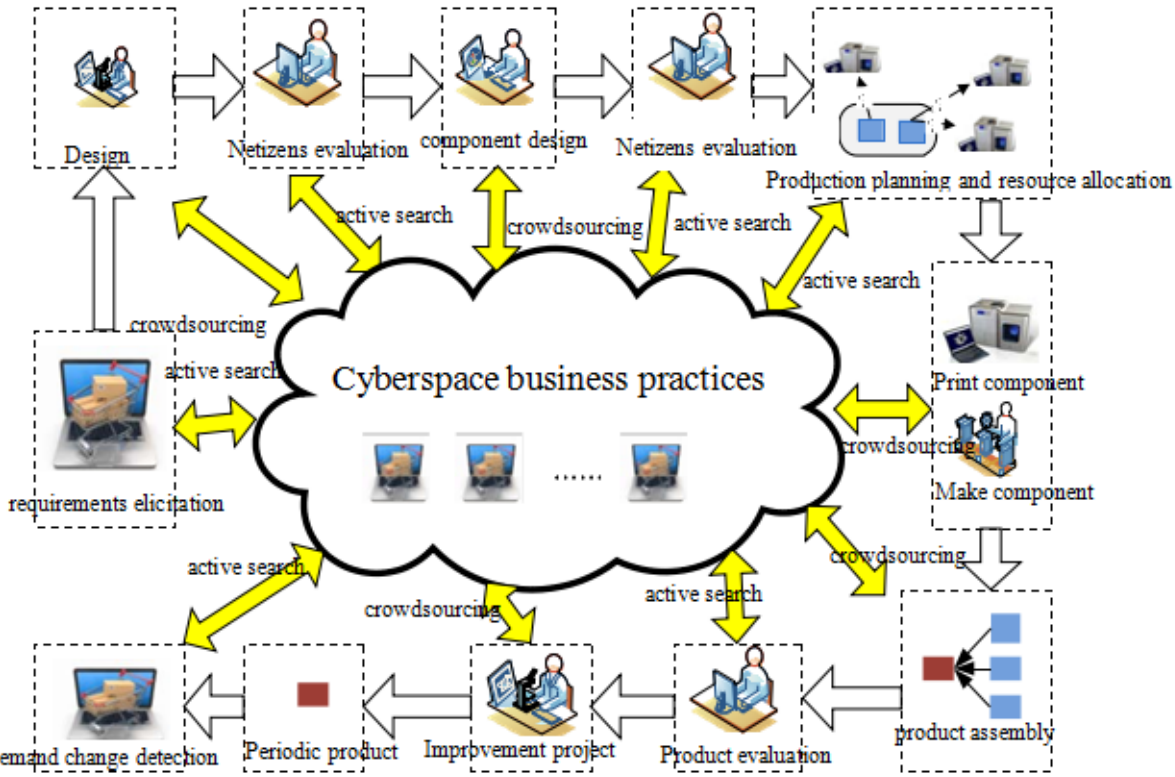

Fig.1: System component

management, so as to make enterprise better adapt to the dynamic and uncertain external environment and enhance the flexibility and agility of the supply chain. As a result enterprise can greatly reduce the customized product delivery and reduce costs to achieve rapid production of customized.

The appraisal and selection of strategic suppliers is the foundation to improve supply chain, to promote the enterprise's competitive competence and the key to meet the rapidly growing customer demand. This paper has established practical supplier evaluation and selection model. Under this model, the selection of supplier has become even more important and with the social manufacturing network platform supplier has become huger, more decentralized and required to be more rapid; general suppliers shall be final retailers.

Based on the traits of more dispersed and more rapid demand of requirements, a supplier's evaluation model is built on the social networking platform. There are several characteristics of selecting supply enterprises. We can summarize as following:

1) Social manufacturing is a manufacturing model that requires "Everyone involved in the design, manufacture and enjoy", that is, it requires everybody to participate in the whole process of product life cycle and enterprises to effectively manage and track the suppliers, which is involved in the whole process. The entire process, from the obtaining of the raw materials to the levels of intermediate processers' processing of the final product, is required to be networking tracked. Problems in any level would have an effluence on the final production efficiency of the enterprise, which make it necessary for the enterprise to take an effective scientific management of levels of various suppliers.

2) Suppliers are mostly final retailers, and supplying materials are mainly natural grown raw materials.

3) Internet suppliers and online procurement

In the 21st century, social manufacturing is a cloud system composed of 3D technology, personalized design, clouds sell and wisdom logistics, under which most suppliers are internet suppliers, which has a model of online e-commerce and offline entity selling and involve the problem of logistic distribution and transportation time. What's more, under cloud computing environments supply chain enterprises are all in the cloud and are virtualized, which provides an opportunity for enterprises providing false information and even deception information to obtain qualification. Therefore, it is more difficult for enterprise to choose a supplier under social manufacturing model than traditional model.

III. Supplier evaluation system based on AHP and fuzzy comprehensive method

In accordance with supplier's characteristics under social manufacturing, this paper puts forward a kind of supplier evaluation system based on AHP and fuzzy comprehensive under the social manufacturing mode. For its evaluation indicators, enterprises not only need to consider the main factors--price, quality and delivery timeliness, but also need to

consider the qualifications of enterprises and its marketing skills.

A. The introduction of AHP and fuzzy comprehensive method

Analytic Hierarchy Process (AHP for short) is a decision-making method for sequencing alternative courses of scheme. This paper shows how AHP can make issue structured, hierarchical, and constructs a hierarchical structure model, which will simplify complex issues [4]. It can use less quantitative information to make thinking process of making decisions mathematical. It has been applied to a wide variety of decision areas, including agriculture and industry.

AHP is a method to rank alternative actions based on the decision made by maker's judgments according to the importance of affecting factors [5]. So it is appropriate for enterprises to select suppliers.

B. Establishment of evaluation system

1) Construct the hierarchical model

The paper uses the evaluation system of AHP and fuzzy comprehensive and two levels of indicators to evaluate suppliers' qualification, which allows the decision maker to separate the multi-element complex problems into several elements and different elements are grouped according to their categories. The system has three levels: the total goal (A), the primary indicators (B), the secondary level indicators (C), different enterprises can choose different indicators according to the needs of enterprises.

2) Establish comparison matrix

When determining the weight between various factors of each level, the method used is put forward by Santy: consistent matrix method, that is, do not put all the factors together for comparison, but do the pairwise comparison with each other. It uses the relative scale to reduce times of comparison between different factors as more as possible and increase accuracy. Judgment matrix is a comparison of relative importance of all factors in this level with respect to any factor in the next higher level, shown as follows. The elements *aij* of judgment matrix is given by Santy 1-9 scaling method [6].

A-Bi	*B1*	*B2*	...	*Bn*
B1	1	a_{12}	...	a_{1n}
B2	a_{21}	1	...	a_{2n}
•	•	•		•
•	•	•		•
•	•	•		•
Bn	a_{n1}	a_{n2}	...	1

The following shows specific meanings of Scale method. Comparing factor *i* and factor *j*, we can get the following scales, shown in table 1

Table1.Comparison of scales: (the meaning of 1 to 9 scales)

Scales	Meaning
1	Factor *i* has the same influence with factor *j*
3	Factor *i* has a slightly stronger influence than factor *j*
5	Factor *i* has stronger influence than factor *j*
7	Factor *i* has much stronger influence than factor *j*
9	Factor *i* has absolutely stronger influence than factor *j*
2,4,6,8	Analogous meanings between the above scales.

3) Single hierarchical sorting

The weight of each element in the given layer can be obtained, after the eigenvector normalization corresponding to the largest eigenvalue $\lambda_{\max}$ of judgment matrix. W represents the sort weights of relative importance between factors in this level and any factor in the last level. The computation of W is called single hierarchical sorting. But in the pairwise comparison matrix series of comparison may account for the deviation. For example, we use pairwise comparison method when comparing the importance of three items-*a, b, c*. The result is that *a* is more important than *b* and *b* is more important than *c,* but *c* is more important than *a,* which is conflicting. So whether it can have single hierarchical sorting, the consistency check need to be done, namely consistency index [7]

$$CI = \frac{\lambda - n}{n - 1} \tag{1}$$

Where: CI is the consistency index;

λ is the largest eigenvalue of judgment matrix;

n is the order of judgment matrix;

In the analytic hierarchy process, the more factors exist in pairwise comparisons, the lower it requirements. To measure the consistency of judgment matrix in different orders, average random consistency index RI of n order is introduced. Random consistency index RI can be found in table 2.

Table2: Random consistency index 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

Define consistency ratio *CR* as formula (2), If *CR*<0.1, inconsistent degree is considered within the allowable range and have a satisfactory consistency. Otherwise, it needs to re-construct pairwise comparative matrix A, by adjusting a_{ij}.

$$CR = \frac{CI}{RI} \tag{2}$$

Where: CR is the consistency ratio;

RI is the random consistency index ;

4) Overall sorting

In order to obtain the relative weights of the second level indicators with respect to the total goal, we need to combine weights of the first and the second level to get the best combining weight (*Wc*) of level elements. It needs to calculate the value of the weight of each index, goes through the consistency examination, and makes the final sequences of the importance of all indexes, denoted by *Wc*. *Wc* expresses the weight of every influence factor and the importance order of every influence factor

C. Fuzzy Synthetic Evaluation

1) establish factor set and evaluation

Factor set contains the factors that affect the evaluation object, namely the second level standard , denoted by F. Evaluators evaluate one object corresponding to a certain factor, obtain a collection of all the possible results which is called evaluation set, denoted by G [8]

2) The fuzzy evaluation

The multi-factor fuzzy evaluation matrix is gained according to the single factor evaluation vector scored by the expert scale. Evaluators will evaluate each of the factors in factor set and map the evaluation results to the factor set to get an overall evaluation Matrix R. The weight of each factor for the total target has concluded by hierarchical analysis, denoted by *Wc*.

3) Fuzzy comprehensive evaluation mathematical model

Known factors set weight vector *Wc* and evaluation matrix R, the fuzzy comprehensive is used to evaluate complex systems. The mathematical model is shown by formula (2)

$$M=Wc*R \qquad (2)$$

Then M is given normalized treatment, obtaining result M', shown in formula (3)

$$V=M' *G' \qquad (3).$$

IV. Evaluation of garment enterprises supplier

In order to verify the feasibility of this method, the evaluation process is shown by using an instance in Dongguan garment enterprises.

1) Establish fuzzy comprehensive evaluation hierarchical model

Through investigating several garment enterprises in Dongguan and analyzing effect of various factors, we have selected sixteen important secondary indicators respectively C1 - C16 and four primary indicators respectively B1 - B4, shown in table3. Fuzzy comprehensive evaluation hierarchical model is obtained and shown in figure 2

2) Calculate weights by using AHP

Through research，we can determine the relative importance of different indicators pairwise comparisons. For example, the indicator *C12* is more important than the indicator *C11*, then value of the first row and the second column in pairwise comparative matrix is *1/2*. It represents that *C12* is twice more important than *C11*, and *C11* is half the importance of *C12*. Sixteen secondary indicators evenly divided into four groups, indicators in each group made pairwise comparison, and established judgment matrix of the lower relative to the upper, that is the following four matrices:

$$\begin{array}{c} \\ C11 \\ C12 \\ C13 \\ C14 \end{array} \begin{array}{c} \begin{array}{cccc} C11 & C12 & C13 & C14 \end{array} \\ \begin{pmatrix} 1 & 1/2 & 1/4 & 1/5 \\ 2 & 1 & 2/4 & 2/5 \\ 4 & 2 & 1 & 4/5 \\ 5 & 5/2 & 5/4 & 1 \end{pmatrix} \end{array}$$

$$\begin{array}{c} \\ C21 \\ C22 \\ C23 \\ C24 \end{array} \begin{array}{c} \begin{array}{cccc} C21 & C22 & C23 & C24 \end{array} \\ \begin{pmatrix} 1 & 1/2 & 1/3 & 1/4 \\ 2 & 1 & 2/3 & 2/4 \\ 3 & 3/2 & 1 & 3/4 \\ 4 & 4/2 & 4/3 & 1 \end{pmatrix} \end{array}$$

$$\begin{array}{c} \\ C31 \\ C32 \\ C33 \\ C34 \end{array} \begin{array}{c} \begin{array}{cccc} C31 & C32 & C33 & C34 \end{array} \\ \begin{pmatrix} 1 & 1/3 & 1/5 & 1/6 \\ 3 & 1 & 3/5 & 3/6 \\ 5 & 5/3 & 1 & 5/6 \\ 6 & 6/3 & 6/5 & 1 \end{pmatrix} \end{array}$$

$$\begin{array}{c} \\ C41 \\ C42 \\ C43 \\ C44 \end{array} \begin{array}{c} \begin{array}{cccc} C41 & C42 & C43 & C44 \end{array} \\ \begin{pmatrix} 1 & 1/3 & 1/5 & 1/6 \\ 3 & 1 & 3/5 & 3/6 \\ 5 & 5/3 & 1 & 5/6 \\ 6 & 6/3 & 6/5 & 1 \end{pmatrix} \end{array}$$

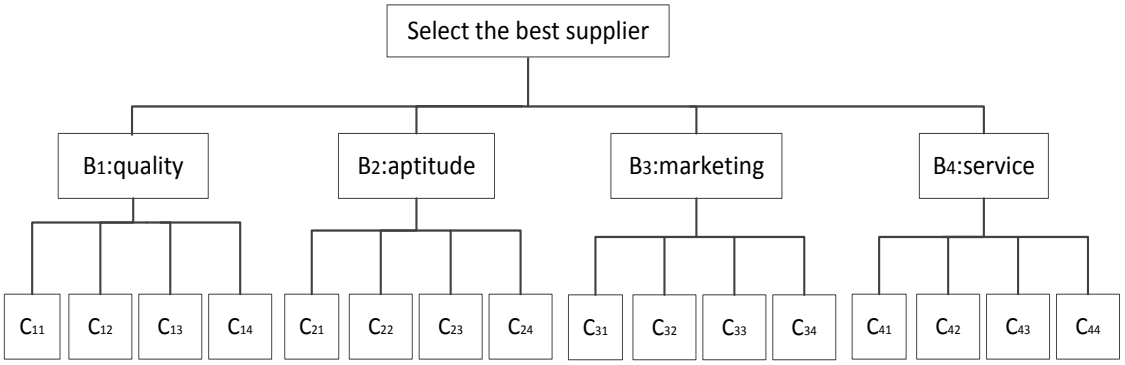

Fig 2: fuzzy comprehensive evaluation hierarchical model

TABLE 3

Primary indicators	Secondary indicators
Quality (B1)	Quality certification (C11)
	product percent of pass (C12)
	Quality inspection and test case (C13)
	quality system (C14)
Enterprise qualification (B2)	R&D ability (C21)
	Market acuity (C22)
	Fixed assets (C23)
	the automation of production (C24)
Marketing (B3)	Product market distribution (C31)
	Product market share (C32)
	marketing method (C33)
	annual sales revenue (C34)
Service (B4)	cost effective (C41)
	after-sales support (C42)
	Product quality qualified rate of delivery (C43)
	The logistics (C44)

Similarly, judgment matrix of the primary indicators was also obtained by pairwise comparison.

$$\begin{array}{c} \\ B1 \\ B2 \\ B3 \\ B4 \end{array} \begin{array}{c} \begin{array}{cccc} B1 & B2 & B3 & B4 \end{array} \\ \begin{pmatrix} 1 & 7/3 & 7 & 7/5 \\ 3/7 & 1 & 3 & 3/5 \\ 1/7 & 1/3 & 1 & 1/5 \\ 5/7 & 5/3 & 5 & 1 \end{pmatrix} \end{array}$$

Then, according to the judgment matrix and AHP algorithm, calculated the weight of each indicator, shown in Table 4 and Table 5.

Table 4 the weight of each secondary indicator

secondary indicators	weight	CI	RI	CR
C11	0.0625	0	0.90	0
C12	0.1875			
C13	0.3125			
C14	0.4375			
C21	0.0833	2.9606e-016	0.90	3.3265e-016
C22	0.1667			
C23	0.3333			
C24	0.4167			
C31	0.0667	0	0.90	0
C32	0.2000			
C33	0.3333			
C34	0.4000			
C41	0.0909	0	0.90	0
C42	0.1818			
C43	0.2727			
C44	0.4545			

Table 5 the weight of each primary indicator

primary indicators	weight	CI	RI	CR
B1	0.4375	0	0.90	0
B2	0.1875			
B3	0.0625			
B4	0.3125			

The combination weight of each indicator is obtained by the above-table: *W= [0.0273 0.0820 0.1367 0.1914 0.0125 0.0375 0.0625 0.0750 0.0042 0.0125 0.0208 0.0250 0.0284 0.0568 0.0852 0.1420]*.

3) Expert evaluation system

Factor set contains sixteen influencing factors and evaluation set G is divided into five results. They are excellent, Good, Moderate, Poor and worse whose corresponding scores is *(95,85,75,60,45)*.Garment enterprises employed 16 experts to make the evaluation of 16 influencing factors set, get the following evaluation matrix *R*.

$$R=\begin{bmatrix} 0.290 & 0.2110 & 0.3160 & 0.1490 & 0.0340 \\ 0.0850 & 0.1770 & 0.4970 & 0.1720 & 0.0690 \\ 0.0870 & 0.1350 & 0.4810 & 0.2060 & 0.0910 \\ 0.0240 & 0.1050 & 0.3970 & 0.3140 & 0.1600 \\ 0.0360 & 0.1280 & 0.4190 & 0.2580 & 0.1590 \\ 0.000 & 0.2470 & 0.3910 & 0.3000 & 0.0620 \\ 0.0310 & 0.3110 & 0.3420 & 0.1520 & 0.1040 \\ 0.2890 & 0.4110 & 0.1670 & 0.1100 & 0.0311 \\ 0.1020 & 0.0590 & 0.4710 & 0.2850 & 0.0830 \\ 0.0270 & 0.0290 & 0.0250 & 0.5440 & 0.3750 \\ 0.0060 & 0.0460 & 0.5610 & 0.3160 & 0.0710 \\ 0.0200 & 0.0970 & 0.3380 & 0.4320 & 0.1130 \\ 0.1280 & 0.2490 & 0.4670 & 0.1100 & 0.0460 \\ 0.3170 & 0.2840 & 0.1960 & 0.2030 & 0.000 \\ 0.0330 & 0.4510 & 0.3740 & 0.1060 & 0.0370 \\ 0.4020 & 0.3250 & 0.2400 & 0.0330 & 0.0000 \end{bmatrix}$$

Using the formula 2, obtained *M*

*M=W*R= [0.1386 0.2322 0.3616 0.1924 0.0746]*.

After normalization, obtained *M'= [0.1386 0.2322 0.3616 0.1924 0.0746]*.

Respectively score matrix which contains five levels: excellent, good, medium, bad, worse: *G= [95 85 75 65 35]*. Finally, using the formula 3, obtained the supplier's score is *V= M'*G'*= 75.1410.

So the level of the supplier is medium.

V *Conclusion*

The system uses the method which combines AHP and fuzzy comprehensive to evaluate suppliers, reducing the impact of people's subjective preferences on evaluation. Verify the system correctness and feasibility by suppliers' strength of garment enterprises.

Acknowledgment

This work is supported by Natural Science Foundation of China Projects (71232006,61233001,61174172), Guangdong Province Science and technology plan projects(2012B090400004), Dongguan's Project of Introducing Innovative R&D Expert (Mr. Gang Xiong), Courtyard Cooperation Project(2F12N02), the Early Career Development Award of SKLMCCS and Guangxi Science and Technology Project (a new generation of intelligent logistics management system development and application demonstration based on the parallel management).

References

[1] Pine, J.B.II., and Boynton, A.Making mass customization work[J] .Harvard Business Review, 1993, 71(5) :108-119.

[2] Xiao Wenfeng, Study on Evaluation of the International Competitiveness of Enterprises (M), Master Degree Thesis of Henan Polytechnic University, 2006: 25 33(in Chinese)

[3] Ghiassi M, Spera C. Defining the Interne-t based supply chain system for mass customized markets[J]. Computers& Industrial Engineering,2003, 45:17-41

[4] Zhang Lianbo．Based on hierarchy analysis method for the choice of the supply chain of distributors application [J]．manager，2010，12：318、324．

[5] Analytical hierarchy process. http://www.rfp-templates.com/Analytical Hierarchy- Process-(AHP).html . 2007

[6] Satty T L.The Analytic Hierarchy process:Planning, priority setting, Resource Allocation. . 1980.

[7] F.T.S. Chan;H.K. Chan;K.L. Choy;. A systematic approach to manufacturing packaging logistics [J]. The International Journal of Advanced Manufacturing Technology,2006.9-10

[8] Jie Zhang, Han Li , Yue Liu;. The improvement and application of fuzzy comprehensive evaluation method under the hybrid information[J]. The 25th China control and decision-making conference proceedings, 2013-05-25.

[9] Hyun Joon Shin;. Collaborative production planning in a supply-chain network with partial information sharing [A]. The International Journal of Advanced Manufacturing Technology[C],2007.9-10

[10] Kazuyoshi Hidaka; Service Scienceservice science , Management, and Engineering SSME (SSME) in Japan [J]. Handbook of Service Science, 2010.

[11] Tetsuro Morimura;Eiji Uchibe;Junichiro Yoshimoto;Kenji Doya; A New Natural Policy Gradient by Stationary Distribution Metric [J]. Machine Learning and Knowledge Discovery in Databases, 2008

[12] DWEIRI F,AL-OQLA F M.Material selection using analytical hierarchy process. International Journal of Computer Applications in Technology . 2006

[13] Amy H. I Lee,Wen-Chin,Ching-Jan Chang.A fuzzy AHP and BSC approach for evaluating performance. Expert Systems With Applications . 2008

[14] Boroushaki S,Malczewski J.Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. Computers and Geosciences. 2008

[15] Saaty T L.Fundamentals of Decision Making and Priority-Theory with the Analytic Hierarchy Process. . 2000