Comprehensive Evaluation and Selection System of Coal Distributors with Analytic Hierarchy Process and Artificial Neural Network

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***Abstract*—Evaluation and selection of coal distributors is one of the most important choices that a coal manufacturer will make new market development. Sales performance and marketing strategy implementation will be directly affected by the result of decision. This paper introduces a computer-aided decision support tool for qualifying potential coal distributors. Based on fast moving consumer goods, this tool, developed as an expert system, provides the user with seven dimensions and specific criteria for arriving at reasonable conclusions by Analytic Hierarchy Process, assesses the accuracy class of those evaluators of by artificial neural network, and demonstrates the comprehensive evaluation methodology for qualifying potential coal distributors. These criteria and related insights form the basis of discussion in the article.**

***Index Terms*—coal distributor evaluation criteria; dynamic assessment; analytic hierarchy process; artificial neural network; accuracy class.**

I. Introduction

After experiencing some mediocre sales from its coal distributor in a key foreign market, a coal manufacturer conducts an investigation as to possible causes. To its surprise and disappointment, the coal manufacturer finds that its coal distributor is also representing another foreign coal manufacturer with competing products.

A coal manufacturer of hospital equipment feels that it is not getting its share of sales in a rapidly industrializing developing country. Discussions with potential customers suggest that the local distributor appointed by the manufacturer suffers from a poor reputation and little political clout.

While generating satisfactory sales in the principal urban city in its territory, a coal distributor fails to capitalize on the market potential of the rest of the nation. A close examination reveals that the distributor has no access to distribution channels outside of the principal city and is not willing to invest in additional sales personnel and physical facilities.

Impressed by the enthusiasm and charisma of its owner/president, a coal manufacturer signs a foreign company as its distributor. The relationship is terminated 3 years later-at a significant cost to the manufacturer. Apparently, despite all the good intentions on the part of the distributor's principal, there was simply no qualified sales and technical team to carry on the responsibilities or the financial resources to expand the business.

These and other real-world experiences are typical of the problems that may arise with coal distributors or agents. The majority of coal manufacturers rely upon local, independent agents and coal distributors when they tap export opportunities in foreign markets. They delegate important business functions to them: physical distribution, sales, customer service, maintenance and warranty, promotion, and so on. When coal distributors are chosen hastily without a thorough examination of relevant qualifications, coal manufacturers are likely to

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be disappointed with their performance. In the worst-case scenario, the manufacturer ends up paying large sums of "severance" payments if it decides to terminate a contracted distributor (Business International, 1985).

Coal manufacturers face ever increasing competition as they try to penetrate markets. Coal distributors or agents carry on the responsibility of marketing the manufacturer's product and servicing customers in the local market. Sales performance and marketing strategy implementation will be directly affected by the result of decision [1]. Since there are uncertain factors, as a result, the effects of extra-dyadic market conditions have been either minimized or ignored in the recent research on evaluation in distributors [2, 3]. The characteristics that contribute to successful distributors are numerous, making it imperative for manufacturers to employ a systematic approach to selection [4].

In the present research, coal distributor effectiveness reflects the extent to which the distributor undertakes key business activities in the distributor's market [5], and the effectiveness of distributors in providing these functions indicates greater value to the channel relationship. Coal distributor effectiveness has been linked to performance, especially with respect to generating revenue and meeting financial objectives [6, 7]. We expect the additional effort and value-added by distributor effectiveness to be reflected in enhanced performance. Trust is one of the most widely recognized mechanisms for governing exchange relationships [8]. Despite the recent advances in research provide the coal manufacturers with certain theoretical basis and practical methods of operation in the choice of distributors, the current knowledge base is limited on more static analysis, dynamic analysis is also rare [9, 10].

The major purpose (contributions) of this paper is as following.

- Based on fast moving consumer goods, this paper introduces a computer-aided decision support tool for qualifying potential distributors.
- Analytic hierarchy process (AHP) and artificial neural network are used to establish the comprehensive evaluation methodology.

II. Research Method

A. Criteria System

Based upon exploratory interviews with seasoned business executives, seven dimensions and specific criteria relevant to qualifying coal distributors are highlighted. We conclude with a discussion of what sound business practices may be adopted for distributor selection decisions. Discussions with these experts, together with existing research on distribution channels, formed the knowledge base for evaluation and selection of distributors. In a series of brainstorming sessions and Delphi studies, the experts agreed upon 32 attributes for systematically evaluating distributors.

B. Analytic Hierarchy Process

The AHP [11], is a method for formulating and analyzing decisions. AHP is a decision support tool that can be used to solve complex decision problems taking into account tangible and intangible aspects. Therefore it helps decision-makers to make decisions involving their experience, knowledge and intuition.

The AHP breaks the decision problem down according to common characteristics, and levels, which correspond to the common characteristic of the elements. The top level is the “focus” of the problem or ultimate goal; the intermediate levels correspond to criteria and sub-criteria, while the lowest level contains the “decision alternatives”. If each element of each level depends on all the elements of the upper level, then the hierarchy is complete; otherwise, it is said to be incomplete. The elements of each level are compared pair-wise with respect to a specific element in the level immediately above.

Table 1 show the pair-wise comparison scale used in Saaty’s [12]. AHP that allows the conversion of qualitative judgments into cardinal values.

TABLE I. The AHP pair-wise comparison scale.

Numerical values	*Verbal scale*	*Explanation*
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favour one element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments
1.1 – 1.9	When two elements are very close but often one would be guessing	Better, the elements are compared with other contrasting elements using 1 – 9 and good answers are obtained

For prioritising elements, a judgment matrix is used;

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

where a_{ij} represents the pair-wise comparison rating between element i and element j in a level with respect to an element in the upper level. Entries a_{ij} are governed by the following rules: $a_{ij} > 0; a_{ij} = 1/a_{ji}; a_{ij} > 1 \forall i.$

Following Saaty [11,13], the priorities of the elements can be estimated by finding the principal eigenvector w of the matrix A,

$$AW = \lambda_{\max} W \tag{2}$$

When the vector W is normalized, it becomes the vector of priorities of elements of one level with respect to the element in the upper level. $\lambda_{\max}$ is the largest eigenvalue of the matrix A. The pair wise comparisons matrix is consistent if it satisfies:

$$a_{ij} = a_{ik} a_{kj}, \ \forall i, j, k \tag{3}$$

Saaty [11] showed that to maintain reasonable consistency when deriving priorities from paired comparisons, more than seven factors need to be considered. The AHP allows inconsistency, but provides a measure of the inconsistency in each set of judgments. The consistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

$$CR = \frac{CI}{RI} \tag{4}$$

where CI is called the consistency index and RI is the random index. Furthermore, Saaty provided average consistencies (RI values) of randomly generated matrices (Table 2). CI for a matrix of order n is defined as:

TABLE II. THE AVERAGE CONSISTENCIES OF RANDOM MATRICES (RI VALUES).

Size	1	2	3	4	5
RI	0.00	0.00	0.52	0.89	1.11
Size	6	7	8	9	10
RI	1.25	1.35	1.40	1.45	1.49

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

In general, a consistency ratio of 0.1 or less is considered acceptable. If the value is higher, the judgments may not be reliable and should be elicited again (Table 2).

Once the local priorities of elements of different levels are available, to obtain the final priorities of the alternatives a_i, the priorities are aggregated as follows:

$$S(a_i) = \sum_k w_k S_k(a_i) \tag{6}$$

where w_k is the local priority of element k and $S_k(a_i)$ is the priority of alternative a_i with respect to element k of the upper level, these 32 criteria are grouped into seven major dimensions and illustrated in Fig. 1.

C. *Artificial Neural Network*

1) *The basic principles of BP neural network*

Ma et al [14] introduced a comprehensive evaluation of the strength of business model by combine with entropy method and BP neural network and a specific algorithm was given. The evaluation of the coal distributors' targets is subject to many variables, metrics and the variables are often interrelated and not independent. Data can be use Artificial Neural Network to train to achieve any of the non-linear mapping [15], and a strong generalization ability for non-linear system of evaluation metrics to provide an effective method, and the structure of typical neuron is shown in Fig. 2.

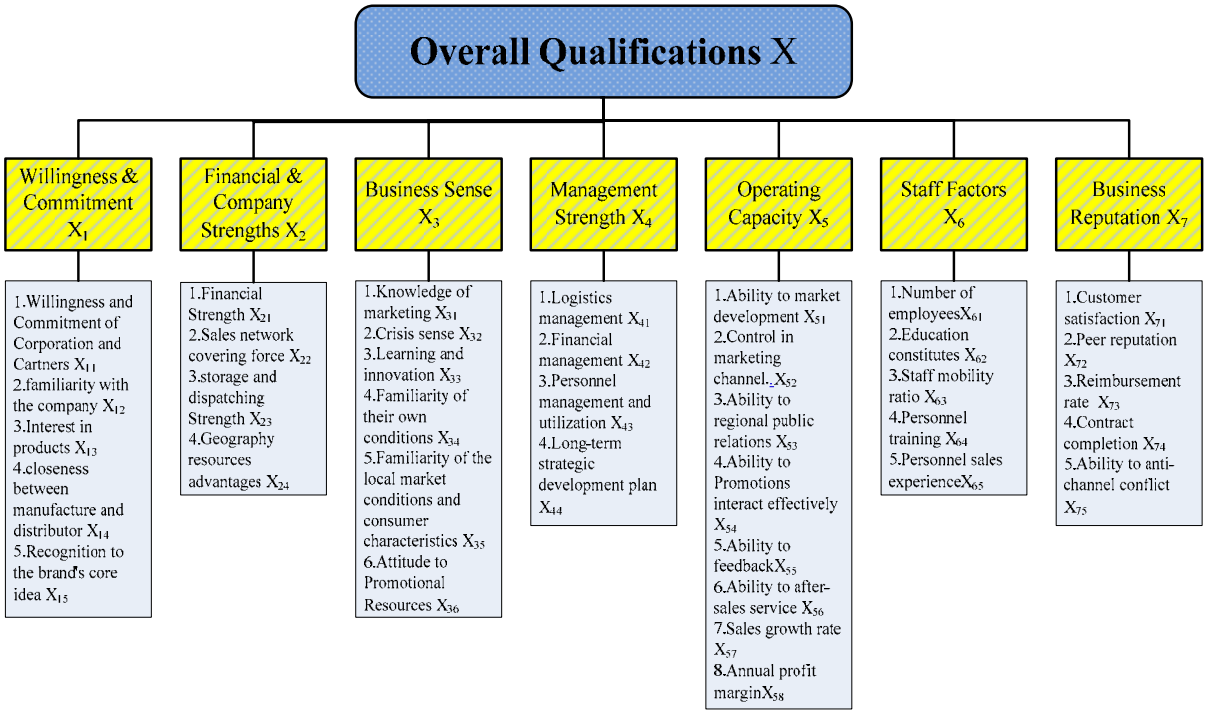


Figure 1. Criteria of evaluating coal distributors

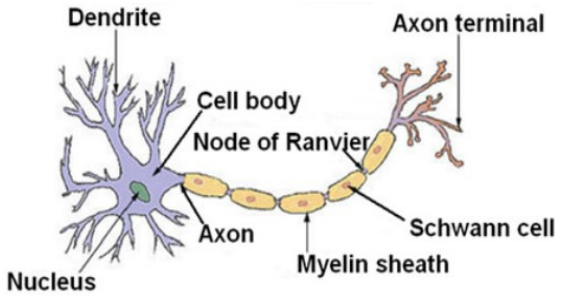


Figure 2. structure of typical neuron

As a result, based on in-depth study of the characteristics of the coal distributors and the establishment of relatively comprehensive, effective, practical, easy-to- distributors assessment index system, it is shown in Fig. 3 of the three-BP neural network .We establish a comprehensive evaluation of the distributors evaluate model and will guide innovative distributors into a standardized evaluation.

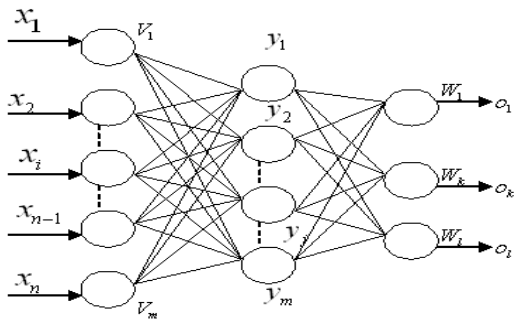


Figure 3. The three-BP neural network

2) Basic steps of BP neural network

a) Determine the parameters of neural network.

According to the listed distributors evaluation system, we determine the parameters of the neural network which, for a number of layers implied, Hema Rao [16] and others pointed out that: there is only one hidden layer neural network, as long as the enough hidden section points, they can approach the precision of a non-linear function, select a number of layers implied. Hidden layer neural units can be set, according to the following rules to determine the hidden layer neuron: the hidden layer neuron is greater than half of the sum of input layer and output layer neurons, less than the sum of input layer and the output neurons [17].

b) Initial the weight assignment.

Initialization of the neural network to connect the right $w_{jk}(0)$ and the value of the neuron $\theta_j(0)$ $w_{jk}(0)$ and $\theta_j(0)$ are small enough for the non-zero random number, which would make a net importer of the initial nodes in the vicinity of zero, so the network to learn faster [18].

c) Enter the study sample.

Each of the study samples, the sample matrix model of the characteristics of the distributors value

$$R_p = \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{22} & \cdots & R_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ R_{P1} & R_{P2} & \cdots & R_{Pn} \end{pmatrix} \quad (7)$$

consist of three targets at a fixed pose, in the order of the evaluation index system.

d) Calculate the sample model hidden layer and output layer units of the actual output value.

For the hidden layer:

$$O_{pj} = f(net_{pj}), \qquad p=1,2,\cdots,P;\ j=1,2,\cdots,m,$$
$$net_{pj} = \sum_{i=0}^{n} V_{ij} R_{pi}, \qquad i=1,2,\cdots,n;\ k=1,2,\cdots,l, \quad (8)$$

For the output layer:

$$Y_{pk} = f(net_{pk}), \qquad p=1,2,\cdots,P;\ k=1,2,\cdots,l,$$
$$net_{pk} = \sum_{j=0}^{m} W_{jk} O_{pj}, \qquad j=1,2,\cdots,m;\ k=1,2,\cdots,l, \quad (9)$$

In eq.(8) and eq.(9), Y_{pk} as a neural network of neuron U_k in the P samples of the actual point output (actual ability to innovate), net_{pk} as that Artificial Neural Network of neuron U_k in the P point samples of input, $f(x) = 1/(1+e^{-x})$ for Sigmoid function [19], V_{ij} for the input neuron from U_i to U_j hidden layer neuron connect the right value. W_{jk} for output neuron connection weights from U_j to the hidden layer neuron U_k to the output neurons.

e) Adjust the value of the threshold.

From the beginning of the output layer, according to the following kinds of reverse of the right to adjust the values of neurons and the threshold:

$$\begin{aligned} W_k(t+1) &= W_k(t) + \eta\delta Y_{pk} + \alpha\left[W_k(t) - W_k(t-1)\right], \\ W_{jk}(t-1) &= W_{jk}(t) + \eta\delta_k Y_{pj} + \alpha\left[W_{jk}(t) - W_{jk}(t-1)\right], \\ \theta(t+1) &= \theta(t) + \eta\delta + \alpha\left[\theta(t) - \theta(t-1)\right], \\ \theta_k(t+1) &= \theta_k(t) + \eta\delta_k + \alpha\left[\theta_k(t) - \theta_k(t-1)\right]. \end{aligned} \quad (10)$$

η is the calculation of the efficiency of learning, and $\eta \in (1,0)$; α for the inertia metric $\alpha \in (1,0)$; t adjusted for the number; δ and δ_k , respectively, said output layer units and output units hidden layer k first unit of output error, and include:

$$\delta = Y_{pk}(1-Y_{pk})(T_{pk} - Y_{pk}), \quad \delta_k = Y_{pk}(1-Y_{pk})\delta W. \quad (11)$$

Where T_{pk} is the distributors' evaluation of the artificial neural network of neuron U_k in the P samples under an ideal point output (expectations).

f) Calculation of E_p and E.

$$E_p = \frac{1}{2}\sum_{k=1}^{l}(T_{pk} - Y_{pk})^2, \quad E = \frac{1}{2}\sum_{k=1}^{l}(T_k - Y_k)^2. \tag{12}$$

When p experienced $1 \sim P$, we should determine whether the targets to meet the requirements of precision. If $E \le \varepsilon$, and ε is the given value for convergence, then end the study, or to Step *e)*.

As a result, the process of evaluating distributors is to evaluate the distributors' value as metrics of specific input into the network layer, the network will be used to adjust the value of a good right to operate a final layer of the output value of distributors. It is an innovative comprehensive evaluation of the value of re-evaluation and standard for comparison, so we can determine their level.

III. CASE STUDY

A. Weight Assignment

Coal manufacturers' focus on the coal distributor is different under different environment condition, if we use the static evaluation indicator system to evaluate distributors, the results will differ greatly with the actual situation. Based on fast moving consumer goods market, we have representative of four kinds of market conditions analyzed, we invited 30 experienced regional sales managers who have worked in fast moving consumer goods for many years to assign weight according to Figure 1. In this research, AHP (Analytic Hierarchy Process) is introduced to determine the weight of indicator, due to a method of index weight setting in multi-criteria synthetically evaluation.

Firstly, they did a pair wise comparison in importance between the indicator and each of its higher indicator in Figure 1, and the 1-9 score is given to the evaluation of importance degree.

Secondly, according to each expert's corresponding matrix, we can find the maximum of all the comparison matrix and its corresponding eigenvector, that is ,the weight indicators in each group at the bottom can be got, and its consistency need to be tested if consistency cannot reach, the indicator will be removed. Finally, the geometric mean of weight evictor given by each evaluator was calculated, and normalized to be the final weight of indicators shown as Table 3 and Fig. 4.

TABLE III. CRITERIA SYSTEM NUMBER BY AHP

New market		Less competitive market		Initial mature market		Mature market system	
Dimension	***Criteria***	***Dimension***	***Criteria***	***Dimension***	***Criteria***	***Dimension***	***Criteria***
X_1(0.18)	X_{11}(0.65)	X_1(0.18)	X_{11}(0.60)	X_1(0.15)	X_{11}(0.53)	X_1(0.10)	X_{11}(0.50)
	X_{12}(0.03)		X_{12}(0.04)		X_{12}(0.05)		X_{12}(0.05)
	X_{13}(0.16)		X_{13}(0.07)		X_{13}(0.15)		X_{13}(0.18)
	X_{14}(0.09)		X_{14}(0.17)		X_{14}(0.18)		X_{14}(0.18)
	X_{15}(0.07)		X_{15}(0.12)		X_{15}(0.09)		X_{15}(0.09)
X_2(0.12)	X_{21}(0.51)	X_2(0.11)	X_{21}(0.49)	X_2(0.08)	X_{21}(0.39)	X_2(0.08)	X_{21}(0.35)
	X_{22}(0.39)		X_{22}(0.37)		X_{22}(0.30)		X_{22}(0.29)
	X_{23}(0.06)		X_{23}(0.08)		X_{23}(0.19)		X_{23}(0.17)
	X_{24}(0.04)		X_{24}(0.06)		X_{24}(0.12)		X_{24}(0.19)
X_3(0.17)	X_{31}(0.10)	X_3(0.12)	X_{31}(0.13)	X_3(0.12)	X_{31}(0.16)	X_3(0.11)	X_{31}(0.18)
	X_{32}(0.03)		X_{32}(0.04)		X_{32}(0.06)		X_{32}(0.05)
	X_{33}(0.04)		X_{33}(0.06)		X_{33}(0.08)		X_{33}(0.10)
	X_{34}(0.05)		X_{34}(0.05)		X_{34}(0.11)		X_{34}(0.11)
	X_{35}(0.47)		X_{35}(0.46)		X_{35}(0.34)		X_{35}(0.35)
	X_{36}(0.31)		X_{36}(0.32)		X_{36}(0.25)		X_{36}(0.21)
X_4(0.15)	X_{41}(0.31)	X_4(0.17)	X_{41}(0.33)	X_4(0.16)	X_{41}(0.34)	X_4(0.18)	X_{41}(0.34)
	X_{42}(0.17)		X_{42}(0.17)		X_{42}(0.19)		X_{42}(0.18)
	X_{43}(0.26)		X_{43}(0.36)		X_{43}(0.41)		X_{43}(0.43)
	X_{44}(0.26)		X_{44}(0.14)		X_{44}(0.06)		X_{44}(0.05)
X_5(0.21)	X_{51}(0.22)	X_5(0.22)	X_{51}(0.28)	X_5(0.29)	X_{51}(0.31)	X_5(0.31)	X_{51}(0.32)
	X_{52}(0.17)		X_{52}(0.17)		X_{52}(0.19)		X_{52}(0.17)
	X_{53}(0.07)		X_{53}(0.09)		X_{53}(0.12)		X_{53}(0.11)
	X_{54}(0.14)		X_{54}(0.12)		X_{54}(0.09)		X_{54}(0.10)
	X_{55}(0.12)		X_{55}(0.13)		X_{55}(0.07)		X_{55}(0.08)

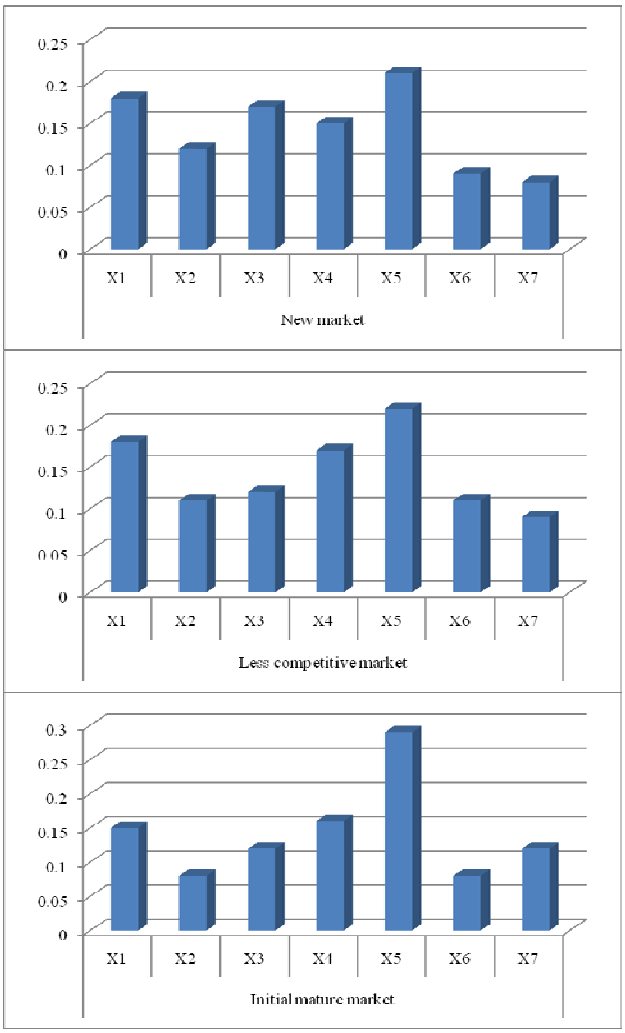
	X_{56}(0.21)		X_{56}(0.12)		X_{56}(0.13)		X_{56}(0.14)
	X_{57}(0.05)		X_{57}(0.05)		X_{57}(0.06)		X_{57}(0.03)
	X_{58}(0.03)		X_{58}(0.04)		X_{58}(0.03)		X_{58}(0.05)
X_6(0.09)	X_{61}(0.03)	X_6(0.11)	X_{61}(0.10)	X_6(0.08)	X_{61}(0.05)	X_6(0.09)	X_{61}(0.04)
	X_{62}(0.06)		X_{62}(0.07)		X_{62}(0.07)		X_{62}(0.08)
	X_{63}(0.46)		X_{63}(0.44)		X_{63}(0.45)		X_{63}(0.43)
	X_{64}(0.10)		X_{64}(0.13)		X_{64}(0.09)		X_{64}(0.10)
	X_{65}(0.35)		X_{65}(0.30)		X_{65}(0.34)		X_{65}(0.35)
X_7(0.08)	X_{71}(0.39)	X_7(0.09)	X_{71}(0.35)	X_7(0.12)	X_{71}(0.36)	X_7(0.13)	X_{71}(0.37)
	X_{72}(0.13)		X_{72}(0.13)		X_{72}(0.14)		X_{72}(0.16)
	X_{73}(0.22)		X_{73}(0.15)		X_{73}(0.23)		X_{73}(0.20)
	X_{74}(0.21)		X_{74}(0.18)		X_{74}(0.16)		X_{74}(0.17)
	X_{75}(0.05)		X_{75}(0.09)		X_{75}(0.11)		X_{75}(0.10)

New market: There is no similar product on the market

Less competitive market: Market is not saturated with a few brands

Initial mature market: There is no monopolistic brand with many brands

Mature market system: There are a few monopolistic brands



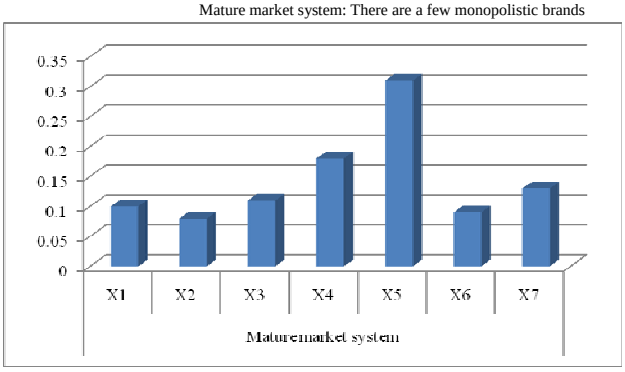
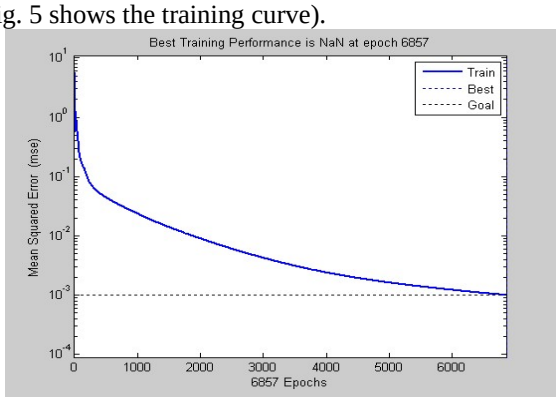


Figure 4. Criteria System number by AHP

B. *Evaluation Based on Artificial Neural Network*

There are a new fast moving consumer goods which will be distribute in Ningbo China, we had 25 market managers evaluated four coal distributors named A, B, C and D with criteria in Fig. 1.The evaluation will be divided into five grades, the evaluation of the level of figures that the number of such "Willingness to cooperate" the column said that there are 15 individuals chose good, 5 personally think better, and so on, and adopt appropriate methods to determine the which hierarchy the distributors belong to.

As a result, when we train model 100000 times, training for the target 0.001, learning rate of 0.05, by the law of entropy input data, BP neural network training (Fig. 5 shows the training curve).



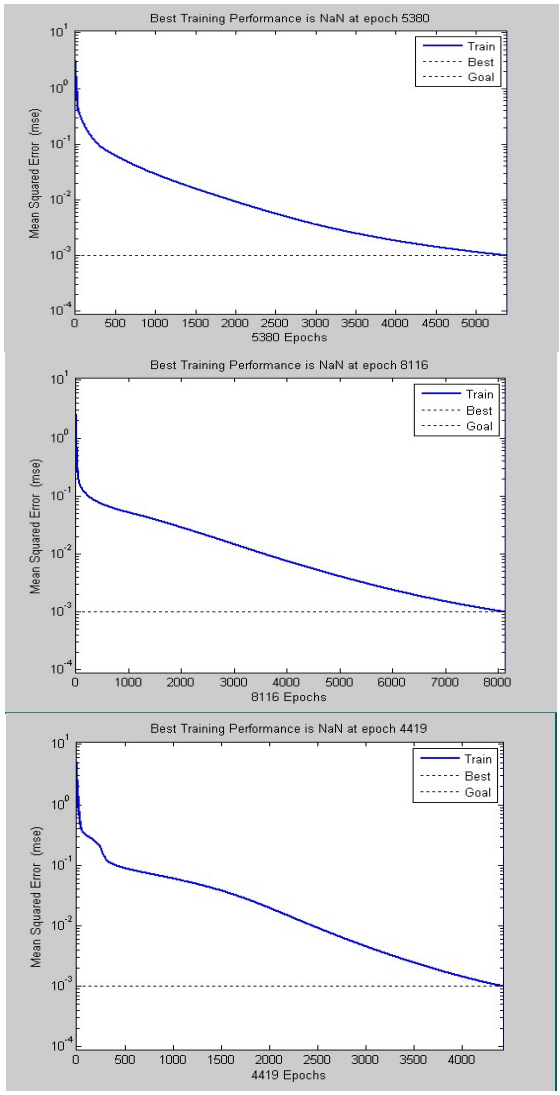


Figure 5. Training of BP neural network

After using artificial neural network, we get the accuracy class of assessment, and then results of evaluation can be obtained, they are shown in Table 4 and Fig. 6.

TABLE IV. RESULTS OF THE EVALUATION

New market				Less competitive market			
C	B	D	A	B	C	A	D
84	79	71	68	88	81	75	71
Initial mature market				**Mature market system**			
D	A	C	B	A	D	B	C
92	85	76	65	87	76	71	65

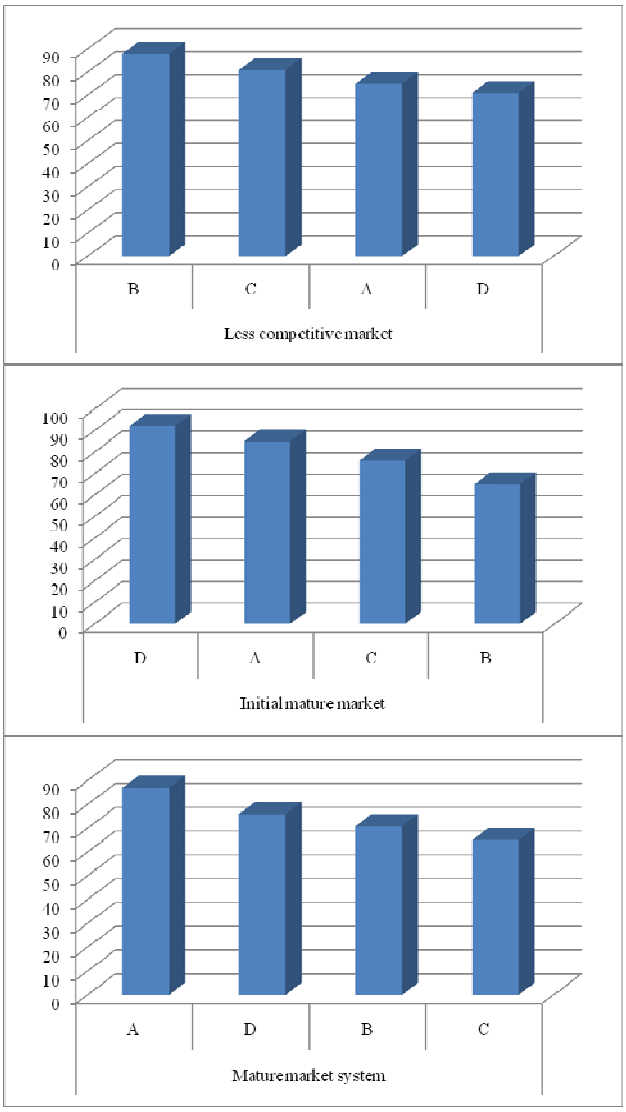


Figure 6. Results of the Evaluation

IV. CONCLUSION AND FUTURE DISCUSSION

Our study includes establishment the evaluation of the criteria for evaluating distributors by the computer- aided decision support tool, the 32 criteria are grouped into seven major dimensions oriented combination of social metrics, through the method of AHP indicators weighting metric, according to BP neural network model of distributors is evaluated as an accurate reflection of their own business conditions to provide a standardized and scientific method, at the same time, we provide manufactures decision-departments a scientific approach to evaluation and select their proper and satisfied distributors, provide marketing researchers with a reference. This paper has following contribution.

- Establishment of seven dimensions and 32 criteria system provides manufactures with an expert system to evaluate their distributors. At the same time, the method of group AHP is imported to empower weight to achieve a fair and reliable result.
- Based on typical changes in the market, we provide four solutions to the dynamic evaluation and selection

of distributors that transformed a static evaluation into a dynamic assessment. The establishment of these models and the actual evaluation of the close ties, combined with the actual situation of solving problems, making the models more practical and universal.

- In solving process, the application of MATLAB software in entropy, as well as BP neural network to determine the level of makes sure that the results are accurate.
- The difference between the results is small, and in a better range, fully demonstrating the superiority of the method.

These research findings suggest possible future research be based on the complicated interaction. Considering the condition of interaction of a number of coal manufacturers and distributors, we will go on in-depth study of optimization problems by particle swarm algorithm, and introduce the idea of complex networks to establish a multi-object network model by using the methods of mathematics modeling and computer simulation.

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