Research on Evaluation System of Alliance Enterprises in Intelligent Manufacturing Environment Based on BP Neural Network

Guiping Xiao, Yunxia Wang, Ping Ni, Di Chen, Zihao Zhang

School of Mechanical Engineering, Nanjing Institute of Technology, Nanjing 21167, China
E-mail: 809024434@qq.com

Abstract: In an intelligent manufacturing environment, fierce global market competition has made more and more companies form industrial alliances to gain an advantage. The basic goal of enterprise alliance is achieving high efficiency and a win-win situation. This paper mainly studies the necessity of partner selection, determines the principle of partner selection, and establishes an evaluation index system for dynamic alliance enterprise cooperation. At the same time, multi-attribute decision analysis and BP neural network are used to identify the ultimate partner. Finally, an example is analyzed with MATLAB to verify its feasibility.

1. Introduction
With the continuous development of network technology, communication technology and advanced manufacturing technology, various competitions among intelligent manufacturing enterprises are increasingly fierce and shifted from confrontation between individual enterprise to various industrial alliances. Under such an environment, competition is too brutal for a single enterprise, only to rely on the cooperation of enterprise alliances to achieve a win-win situation.

There are a few but not many research results for alliance enterprises under the intelligent manufacturing environment in global [1-5]. However, the development trend is multiple stages in stages and comprehensive use of different methods. This paper studies the selection and evaluation system of alliance enterprise partners, determines the selection principles and evaluation index system, uses the multi-attribute decision method to gain the evaluation index weights and uses the BP neural network evaluation algorithm to select partners.

2. Establishment of alliance enterprise evaluation system in the intelligent manufacturing

2.1. The selection principle of alliance enterprises in the intelligent manufacturing environment
The evaluation and selection of partners is the basis for the operation of enterprise alliances. In the intelligent manufacturing environment, the choice of partners has an increasing impact on such as product innovation, product design, intelligent manufacturing, product flexibility (delivery, product quality, lead time), inventory level and other aspects.

In order to achieve the low cost, high quality, flexible production, quick response, and make factories operate smoothly, the evaluation and selection of partners is significant. The alliance can be either an industrial alliance or a supply chain alliance. Industrial alliances are consisted of companies that can maintain oneself's competitive advantages while using each other's superior resources to
compete with other companies in the same industry. The supply chain alliances cover the entire supply chain of products to strengthen the competitiveness and value-added power of the enterprise. Alliance partners are divided into important partners and general partners. Important partners are tightly coupled partners who are few and precise, important and interest-related; while general partners are loosely coupled partners that are more and have cooperative relations but not close. When choosing alliance partners, value-added power and competitiveness are two important factors.

In the operation of alliance enterprises, different types of partners should be selected according to requirements, goals, and interests. For long-term needs, partners are required to maintain high competitiveness and value-added power; for short-term or short-term market needs, ordinary partners can meet the demand to ensure the minimal costs; for medium-term needs, different types of partners (influential or competitive/technical partners) can be selected according to the importance of competitiveness and value-added power to the supply chain.

2.2. Establishment of alliance enterprise evaluation system

According to the investigation of enterprises, the comprehensive evaluation index system of enterprises in the industry alliance is constructed. According to the two general goals: competitiveness and value-added power, the stratified goals and evaluation indicators are gradually determined. Different from the evaluation indicators of traditional alliance enterprises, alliance enterprises in the intelligent manufacturing environment highlight the five goals of intelligent manufacturing level, production flexibility, big data integration capability, innovation and creativity, and product quality and the goals are divided into 18 indicators, (which are intelligent equipment level IEL, perception technology application PTA, intelligent learning ability ILA, production capacity PC, time flexibility TF, quantity flexibility QF, variety flexibility VF, enterprise internal data EID, enterprise external data EED, data integration capability DIC, information level IL, number of patent applications NPA, number of R&D personnel R&D, high and new technology HNT, expenditure input EI, quality level QL, product specifications PS, quality standard QS), as shown in Figure 1.

3. Determination of alliance partners

In view of the diversity of indicators, multi-attribute decision analysis is used to determine the weight of the indicator attributes and the BP neural network is used to evaluate the partners.

(1) Multi-attribute decision analysis

During the comprehensive evaluation of cooperative partners with multiple factors, various indicators are uncountable due to different dimensions. Therefore, unified standards or norms is made by multi-attribute decision analysis to evaluate the indicators dimensionlessly, that is, to map the value to the [0,1] interval to obtain the membership degree. The principle of multi-attribute decision analysis
is to make a decision on a group or a limited number of alternatives in a special way. The main steps include:

1) Obtain decision information. Decision information generally includes attribute weight and attribute value.

2) Aggregate the decision information and sort and select the schemes in a certain way. The attributes are divided into different types such as benefit type, cost type, fixed type and deviation type to ignore different dimensions. The larger the benefit-type attribute value, the better; the smaller the cost-type attribute value, the better; and the fixed type, the closer the attribute value to a certain fixed value, the better. When making a decision, the following formula can be used to normalize the data:

Benefit attributes:

\[ r_i = \frac{a_i - \min_{j} a_j}{\max_{j} a_j - \min_{j} a_j} \]  

(1)

Cost attributes:

\[ r_i = \frac{\max_{j} a_j - a_i}{\max_{j} a_j - \min_{j} a_j} \]  

(2)

Fixed attributes:

\[ r_i = 1 - \frac{a_i - \alpha_i}{\max_{j} |a_j - \alpha_j|} \]  

(3)

(2) Application of BP neural network

BP neural network is a branch of Artificial Neural Network (ANN). ANN is an emerging discipline which can simulate certain intelligent behaviors of the human brain, such as perception, inspiration and image thinking, etc. and have the characteristics of self-learning, adaptive and non-linear dynamic processing. ANN develops rapidly since the late 1980s. The neural network is applied to the comprehensive evaluation and selection of partners in intelligent manufacturing environment to establish a comprehensive evaluation and selection model that is closer to human thinking patterns and that is the combination of qualitative and quantitative. Through the study of a given sample, the knowledge, experience, subjective judgment of the evaluation experts and the tendency to the importance of the target are acquired. When a comprehensive evaluation of partners is made, this method can reproduce some related characteristics of the evaluation experts, thus achieving an effective combination of qualitative and quantitative analysis to guarantee the objectivity of the results.

Before using the neural network for comprehensive evaluation, the input value is converted into a value between [0, 1] through the multi-attribute decision analysis membership function to unify dimension. The diagram of the processing function structure of the input is shown in Figure 2.

![Figure 2. Alliance Enterprise Evaluation Index Input Module](image)

\( x_{i} \) represents the evaluation value (input value) of the \( i \) indicator. \( y_{pi} \) represents the quantified evaluation value (output value) of the \( i \) indicator, which is the input value of the BP network. The BP artificial neural network (BP network) can be described as a network structure with an input layer, a hidden layer, and an output layer. Each layer has multiple nodes and each adjacent two layers are interconnected in one direction, as shown in Figure 3.
The calculation formula of the hidden layer $y_j$ are as follows:

$$\sum_{i=1}^{n} C_i > k \quad i = [0,1,...,n]$$

$$q = \sqrt{n + m + a} \quad a = [0,1,...,n]$$

$$q = \log_2 n$$

In the formula, $n$, $q$, and $m$ respectively represent the number of neurons in the input layer, hidden layer, and output layer.

Corresponding number of neurons in the best hidden layer can be calculated through formula above, which reflects the convergence speed and error of the neural network. An optimal number of hidden layers can be obtained finally by the same method [6]. After the weights and thresholds of the network are obtained, the initialized enterprise evaluation value can be used as the network input to gain the evaluation output.

4. Case study

Suppose that the participating enterprises (which can provide the same project to the manufacturer) are S1, S2, S3, S4, and S5 when an intelligent manufacturing company chooses an industry alliance partner. and the above evaluation system is used for collecting data and determining the final partner. 18 evaluation indicators of each enterprise are collected and an intelligent decision analysis model is applied to standardize the data: $i = 1, 2, ..., 18$ (i is the number of indicators); $j = 1, 2, ..., 5$ (j is the number of research object), the original data and the dimensionless values are shown in Table 1.

| Sample          | S1 | S2 | S3 | S4 | S5 |
|-----------------|----|----|----|----|----|
| Intelligent Equipment Level (article) | 23 | 16 | 40 | 15 | 5  |
| Perception technology application (mm) | 2  | 52 | 115| 22 | 62 |
| Intelligent learning ability (point) | 14 | 13 | 14 | 13 | 16 |
| Production capacity (ton) | 45 | 10 | 45 | 10 | 40 |
| Time Flexibility (%) | 60 | 30 | 40 | 30 | 40 |
| Quantity flexibility (mm) | 4  | 3  | 1  | 2  | 2  |
| Variety Flexibility (%) | 30 | 40 | 45 | 60 | 42 |
| Enterprise internal data (mm) | 2  | 5  | 5  | 4  | 5  |
| Enterprise external data (point) | 8  | 7  | 5  | 5  | 8  |
| Data integration capability (point) | 4  | 5  | 6  | 7  | 3  |
| Information level (point) | 9  | 3  | 6  | 7  | 4  |
| Number of patent applications (mm) | 21 | 30 | 10 | 24 | 46 |
| High and new technology (mm) | 4  | 3  | 5  | 2  | 2  |
| Number of R & D personnel (digit) | 60 | 120| 300| 40 | 10 |
| Expenditure input (mm) | 12 | 28 | 20 | 5  | 12 |
| Quality level (point) | 16 | 15 | 10 | 16 | 17 |
| Product specifications (point) | 8  | 7  | 6  | 5  | 8  |
| Quality standard (mm) | 4  | 5  | 6  | 7  | 3  |

| Sample          | S1 | S2 | S3 | S4 | S5 |
|-----------------|----|----|----|----|----|
| Equipment Application Level | 0.25 | 0.20 | 0.15 | 0.20 | 0.25 |
| Perception technology application | 1.00 | 0.35 | 0.30 | 0.35 | 1.00 |
| Intelligent learning ability | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| Production capacity | 0.41 | 1.00 | 0.94 | 0.75 | 0.60 |
| Time flexibility | 0.30 | 0.30 | 0.40 | 0.40 | 0.60 |
| Quantity flexibility | 0.60 | 0.40 | 0.40 | 0.20 | 0.80 |
| Variety Flexibility | 0.50 | 0.75 | 0.55 | 0.36 | 0.50 |
| Enterprise internal data | 0.60 | 0.60 | 1.00 | 1.00 | 0.40 |
| External data of the enterprise | 0.70 | 0.00 | 0.60 | 0.00 | 0.60 |
| Data integration capability | 0.50 | 1.00 | 0.30 | 0.60 | 0.00 |
| Information level | 0.30 | 0.70 | 0.40 | 0.60 | 0.00 |
| Number of patent applications | 0.23 | 0.16 | 0.30 | 1.00 | 0.14 |
| High and new technology | 0.50 | 0.35 | 1.00 | 0.50 | 0.67 |
| Number of R & D personnel | 0.60 | 0.50 | 0.05 | 0.00 | 0.00 |
| Expenditure input | 0.50 | 0.04 | 0.04 | 0.70 | 0.74 |
| Quality level | 0.75 | 0.00 | 0.50 | 0.50 | 0.00 |
| Product specifications | 0.70 | 0.50 | 0.50 | 0.60 | 0.50 |
| Quality standard | 0.50 | 0.70 | 0.30 | 0.60 | 0.40 |
Based on the introduction of the neural network algorithm, the minmax function is used in Matlab to find the calculation result of the input sample data range, and the recursive operation is performed on the evaluation target using the normalization formula. Control variables are complementary if there is obvious correlation between each variable of the same object, and the value of $X$ is the average value; control variables are non-complementary if there is no obvious correlation between each control variable, and the value of $X$ is the smallest of a set of big values. Finally, the total evaluation value of the evaluation object is obtained. The normalization formula of each mutation system is gradually integrated upwards until the overall evaluation result is obtained. As shown in Figure 4.

According to the same calculation method and steps, other intelligent manufacturing selection evaluation scores, as well as the corresponding performance output level, informatization level, innovation level and intelligent manufacturing management level are obtained. The evaluation corresponding ranking results are shown in Table 2.

**Table 2.** Evaluation and corresponding ranking results

| Partner | Score | Ranking |
|---------|-------|---------|
| S1      | 0.6483| 3       |
| S2      | 0.4235| 4       |
| S3      | 0.7366| 2       |
| S4      | 1.2445| 1       |
| S5      | 0.1823| 5       |

5. Conclusion
The alliance enterprise is a brand-new organization form which is the main mode of market competition and production management of enterprises in the 21st century in the intelligent manufacturing environment. Partners are popular in the world with rapid response, complementary advantages, and flexible management. The selection of partners is directly related to the survival and development of the enterprise. Therefore, this paper focuses on the construction principles of evaluation indicators, the establishment of evaluation indicator systems, the application of multi-attribute decision analysis, neural networks to evaluate the results of reasonable selection of partners in the dynamic alliance. Finally, MATLAB is used to calculate example to verify its rationality.

Acknowledgments
This research is sponsored by Ministry of Education, Humanities and Social Sciences Project of China (No.16YJCZH108, No.17YJCZH083). Major projects of the School level Innovation Fund (CKJA201509).

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