Chapter 14
Partner Selection and Optimization Based on Manufacturing Resource Sharing Platform for Virtual Enterprise

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Abstract In the environment of economic globalization, this paper proposed partner selection and optimization based on manufacturing resource sharing platform for virtual enterprise. Firstly, a comprehensive evaluation system for virtual enterprise partner selection was established. Secondly, the weight of evaluation was defined based on the market conditions and nature of the project by analytic hierarchy process (AHP). Thirdly, a multi-objective optimization model for virtual enterprise partner selection was established. Fourthly, an optimal combination scheme was solved by self-adaptive genetic algorithm. Finally, effectiveness of partner selection and optimization for virtual enterprise was proved by an example.

Keywords Virtual enterprise · Partner selection · Analytic hierarchy process · Genetic algorithm

14.1 Introduction

With formation of global network economy, the competition of manufacturing is not on individual enterprise but on complementary advantage and resource optimization and supply chain and industry chain. Virtual Enterprise has become an

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important trend in commercial activities. It can integrate the advantage of resource among different enterprises. So it cans response to market opportunity rapidly [1].

Manufacturing resource sharing platform is an integration solution based on the industry supply chain. It can make inter-enterprise information interoperability and data sharing and business interaction facilitate. It allows knowledge and ideas greater exchange and information and resource wider use. Thus the efficiency of business activities can be improved greatly. Meanwhile, the chief of virtual enterprise can find the best business partners on manufacturing resource sharing platform [2].

Partner selection and optimization is the key for virtual enterprise. Therefore it has important theoretical and practical significance. Many scholars at home and abroad have been done about this problem. However, they basically focused on the qualitative or quantitative. This paper proposed a new method of partner selection for virtual enterprise between qualitative and quantitative analysis. AHP was adopted to determine the evaluation index weight based on the virtual enterprise comprehensive evaluation system and market conditions. Then a multi-target partner selection optimization model for virtual enterprise was established. Then candidate companies were searched on manufacturing resource sharing platform. Finally, the optimal combination was obtained through self-adaptive genetic algorithm.

14.2 Comprehensive Evaluation Index and Weight for Virtual Enterprise

14.2.1 Comprehensive Evaluation Index System for Virtual Enterprise

A scientific and complete comprehensive evaluation index system must be established for Virtual Enterprise partner selection. There are many factors that can affect the virtual enterprise partner selection. According to the different opportunity, the emphasis is different. Predecessors have done a lot of research on the evaluation index system, but there have different evaluation index system for different industry. This paper summarizes and analyzes a comprehensive evaluation system for machinery manufacturing industry.

Generally, Time (T) and Quality (Q) and Cost (C) are used to evaluate the competitiveness of an enterprise [3]. This paper suggests increasing Innovation (I) and Advancement (AD) and Credit (CR) and Management & Culture (MC) and Environment (E) for machinery manufacturing comprehensive evaluation system. The comprehensive evaluation system was divided into three levels. The first layer was the overall goal to find the best partners. The second level has eight criteria: T, Q, C, I, AD, CR, and MC, E. The third layer is more detailed guidelines. Specific was shown in Fig. 14.1.

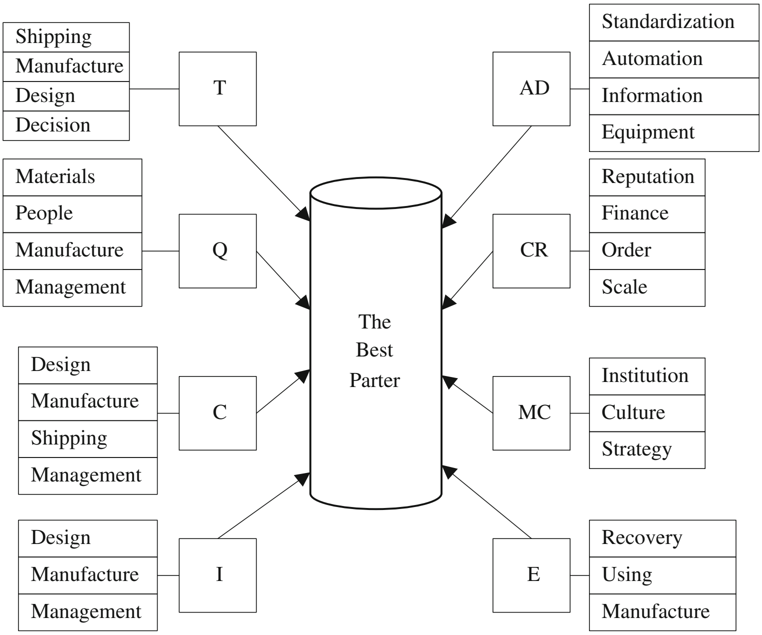

Fig. 14.1 Comprehensive evaluation index system for virtual enterprise

14.2.2 Determination for the Weight of Virtual Enterprise Comprehensive Evaluation Index

There are many factors that can affect the virtual enterprise partner selection, and these factors are often contradictory. In order to get optimal result, this paper use multi-objective planning approach and AHP to determine weight of evaluation index rationally. Specific steps are as follows:

According to specific market objective and specific circumstance of the project, the index of partner selection evaluation was determined. The determination can refer to the virtual enterprise comprehensive evaluation system.

Nine-bit table was used to select the importance of the evaluation. The ratio of the relative importance was shown on Table 14.1.

According to the specific situation, the expert of the project compares the index of evaluation by pairwise. Then a reciprocal matrix was got. The equation is as follow [4]:

Table 14.1 The ratio of the relative importance

Definition	Equally important	Somewhat important	Obviously important	Strongly important	Extremely important	Among
Value	1	3	5	7	9	2, 4, 6, 8

$$R_m = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$$

where, m is the number of experts. n is the number of index. r_{ij} is the ratio of two index. r_{ij} satisfy: $r_{ij} \times r_{ji} = 1$.

In AHP evaluation, the geometric average score is a good approach to summarize the expert opinion. The equation is as follow.

$$\bar{r}_{ij} = \left(\prod_{i=1}^{m} r_{ij}^{(l)} \right)^{\frac{1}{m}}$$

where, m is the number of experts, $r_{ij}^{(l)}$ is the evaluation value by the lth experts, $l = 1, 2, \ldots, m$. The new matrix is

$$\overline{R} = \begin{bmatrix} \overline{r_{11}} & \overline{r_{12}} & \cdots & \overline{r_{1n}} \\ \overline{r_{21}} & \overline{r_{22}} & \cdots & \overline{r_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \overline{r_{n1}} & \overline{r_{n2}} & \cdots & \overline{r_{nn}} \end{bmatrix}$$

Solution for the maximum eigenvalue of matrix $\bar{R}$.

Eigenvectors are standardized to make the sum of Eigenvectors is 1. After Standardization, the Eigenvectors is the weight of index.

Based on the above steps, the eight index of virtual enterprise comprehensive evaluation system is $R = \{T, Q, C, I, AD, CR, MC, E\}$. The corresponding weight vector is $R = \{T, Q, C, I, AD, CR, MC, E\}$

14.3 The Multi-Objective Partner Selection Model for Virtual Enterprise

14.3.1 Description for Model

The project will be broken down into N independent sub-tasks by the chief of virtual enterprise and denoted as: $T = \{T_0, T_1, T_2, \ldots, T_n, T_{n+1}\}$, where T_0 and T_{n+1} is the virtual task. The corresponding workload is recorded as: $Q = \{Q_0, Q_1, Q_2, \ldots, Q_n, Q_{n+1}\}$, where the workload of Q_0 and Q_{n+1} is 0 h.

The timing relationships between sub-tasks is shown by $T\_Seq = \{ (T_i, T_j | i,j \in [0, n+1]), i \neq j, T_i, T_j \in T\}$, where T_j is the direct follow-up T_i [8, 9]. All enterprises is denoted as: $E = \{E_{ij} \mid i \in [1, n], j \in [1, m]\}$, where n is the total number of sub-tasks, m is the number of candidate enterprises for the task Ti. $E_{ij} \neq 0$

indicates that the candidate enterprises effective, Ti can select one or more candidate companies [5]. The information of each candidate enterprise is recorded as E_Info = {(start_fee$_{ij}$, per_fee$_{ij}$, per_qua$_{ij}$, Q_{ij}, I_{ij}, AD_{ij}, CR_{ij}, MC_{ij}, E_{ij}), i ∈ [1, Num], j ∈ [1, Param]}, where Num $= \sum_{i=1}^{n} m_i$ is the total number of company for the project, Param is the number of evaluation index.

14.3.1.1 Establishment of the Multi-Objective Optimization Model

In order to evaluate effect of the virtual enterprise partner selection, the multi-objective optimization model must be established. Firstly, define the following function [6].

$$S_{ij} = \begin{cases} 1 & 38; T_i \text{ select jth candidate enterprise} \\ 0 & 38; T_i \text{ not select jth candidate enterprise} \end{cases}$$

The various of single-objective function can be expressed as follows:

$$Min(T) = t_{n+1} \tag{14.1}$$

Equation (14.1) t_{n+1} is the completion time of Tn +1, that is also the project finish time. Transform the Eq. (14.1) into a maximization problem:

$$Max(T^{'}) = C - t_{n+1} \tag{14.2}$$

where, C is a large enough positive number to ensure $C - t_{n+1} \geq 0$.

$$\text{Min}(C) = \sum_{i=1}^{n} \sum_{j=1}^{m} (start\_fee_{ij} + q_{ij} \times per\_fee_{ij}) \times S_{ij} \tag{14.3}$$

Equation (14.3) q_{ij} is the workload that the chief of virtual enterprise assigned to E_{ij}, $\sum_{j=1}^{m} q_{ij} = Q_i$. Transform the Eq. (14.3) into a maximization problem:

$$Max(C') = C - \sum_{i=1}^{n} \sum_{j=1}^{m} (start\_fee_{ij} + q_{ij} \times per\_fee_{ij}) \times S_{ij} \tag{14.4}$$

where, C is a large enough positive number to ensure $C - \sum_{i=1}^{n} \sum_{j=1}^{m} (start\_fee_{ij} + q_{ij} \times per\_fee_{ij}) \times S_{ij} \geq 0$.

$$\text{Max}(Q) = \sum_{i=1}^{n} \sum_{j=1}^{m} Q_{ij} \times S_{ij} \tag{14.5}$$

$$\mathrm{Max}(I) = \sum_{i=1}^{n}\sum_{j=1}^{m} I_{ij} \times S_{ij} \tag{14.6}$$

$$\mathrm{Max}(AD) = \sum_{i=1}^{n}\sum_{j=1}^{m} AD_{ij} \times S_{ij} \tag{14.7}$$

$$\mathrm{Max}(\mathrm{CR}) = \sum_{i=1}^{n}\sum_{j=1}^{m} CR_{ij} \times S_{ij} \tag{14.8}$$

$$\mathrm{Max}(MC) = \sum_{i=1}^{n}\sum_{j=1}^{m} MC_{ij} \times S_{ij} \tag{14.9}$$

$$\mathrm{Max}(E) = \sum_{i=1}^{n}\sum_{j=1}^{m} E_{ij} \times S_{ij} \tag{14.10}$$

Eventually, the multi-objective problem was transformed into a single objective problem. The index weights models (14.11) can be got by AHP and combining the equations of (14.2, 14.4–14.10).

$$\begin{aligned} \mathrm{M}ax(Total) = \omega_t \times \mathrm{M}ax(T^{'}) + \omega_{\mathrm{q}} \times \mathrm{M}ax(Q) + \\ \omega_{\mathrm{c}} \times \mathrm{M}ax(C^{'}) + \omega_{\mathrm{i}} \times \ \mathrm{M}ax(I) + \omega_{\mathrm{ad}} \times \mathrm{M}ax(AD) + \\ \omega_{\mathrm{cr}} \times \mathrm{M}ax(CR) \ + \omega_{\mathrm{mc}} \times \mathrm{M}ax(MC) \ + \omega_{\mathrm{e}} \times \mathrm{M}ax(E) \end{aligned} \tag{14.11}$$

$$\text{s.t. } \mathrm{q_{ij}} \geq 0 \tag{14.12}$$

$$\sum_{\mathrm{j}=1}^{m} q_{ij} = Q_i, \quad i = 1, 2, \ldots, n \tag{14.13}$$

$$\mathrm{S}_{ij} = \begin{cases} 0 & q_{ij} = 0 \\ 1 & q_{ij} > 0 \end{cases} \tag{14.14}$$

14.4 Model Solution Based on Genetic Algorithm

14.4.1 Arithmetic Coding

According to the model, the encoding of virtual enterprise is [3]:

$$\begin{pmatrix} s \\ q \end{pmatrix} = \begin{pmatrix} s_{11} & \cdots & s_{1m} & \cdots & s_{n1} & \cdots & s_{nm} \\ q_{11} & \cdots & q_{1m} & \cdots & q_{n1} & \cdots & q_{nm} \end{pmatrix} \tag{14.15}$$

where, s is the selected vector of all candidates enterprises, encoding using integer 0−1, $s_{ij} = 0$ or 1, indicating whether the candidate enterprise is selected; q is the task vector of all candidate enterprise assigned, using real-coded, q_{ij} is the workload assigned to E_{ij}.

14.4.2 Design Objective Function

Supposed the scale of group is Popsize, according to equations of (14.2, 14.4–14.10), a single-target value of individual is calculated on the same generation. Each single-target value is order from small to large. According to the index weight, the overall fitness of individual is got. P_k is defined as follows:

$$P_k = q_{\max} - (k-1) \times (q_{\max} - q_{\min})/(Popsize - 1) \tag{14.16}$$

where, q_{max} and q_{min} represent the selection probability of best and worst chromosomes. After determining the probability of each individual, the selection follow the roulette algorithm.

14.4.3 Self-Adaptive Across and Variation

The self-adaptive across and variation is used in this paper.

$$P_c = \begin{cases} \frac{P_{c\_\max} - (P_{c\_\max} - P_{c\_\min})(k - midst)}{Popsize - midst} \times \delta(g) & k \geq midst \\ P_{c\_\max} \times \delta(g) & k < midst \end{cases} \tag{14.17}$$

$$P_m = \begin{cases} \frac{P_{m\_\max} - (P_{m\_\max} - P_{m\_\min})(Popsize - k')}{Popsize - midst} \times \delta(g) & k' \geq midst \\ P_{m\_\max} \times \delta(g) & k' < midst \end{cases} \tag{14.18}$$

where, $\delta(g) = 1 - g/(\gamma \times Gen)$; $midst = \lfloor Popsize/2 \rfloor$.

g is the No. of present generation; Gen is the largest generation; γ is factor; $P_{c\_\max}$ and $P_{c\_\min}$ is the across probability of maximum and minimum; $P_{m\_\max}$ and $P_{m\_\min}$ is the variation probability of maximum and minimum; k is the ranking of individual cross, k' is the ranking of individual variation [3].

14.5 Conclusion

The virtual enterprise partner selection problem was studied based on manufacturing resource sharing platform in this paper. A comprehensive evaluation index system for virtual enterprise has been established. The weight of each evaluation index has been determined by AHP. The multi-objective optimization model for virtual enterprise partner selection has been established. The solution process of self-adaptive genetic algorithm has been designed.

In Matlab 6.5 platform, the optimization algorithm was achieved. The effectiveness of new methods was proposed in this paper was proved through an example. The result using self-adaptive genetic algorithm is close to the actual situation. It is indicated that the new virtual enterprise partner selection method is effective for practical problems.

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