Application of Fuzzy Analytic Hierarchy Process in Intelligent Manufacturing Resources Allocation Evaluation System of Alliance Enterprises

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Abstract. With the increasing global competition, more and more enterprises form the industrial alliance. In order to solve the problem of resource allocation and scheduling optimization of industrial alliance enterprises in intelligent manufacturing environment, an efficient resource allocation method and evaluation index of industrial alliance service platform are established. A set of systematic intelligent manufacturing resources evaluation scheme is established by using FAHP, which can be used to evaluate and analyze several manufacturing resources conveniently. According to different needs of customers, the weight assignment is also changing, and the most suitable manufacturing resources can be obtained.

1. Introduction
With the development of science technology and the increasing of global competition, manufacturing enterprises need to face more and more severe challenges. In order to survive and win, many enterprises form industrial alliance actively. Through resource sharing, technology sharing and other mutually beneficial policies to jointly deal with competition, to achieve the long-term and stable development of alliance enterprises.

Under the intelligent manufacturing environment, in order to realize beneficial policies among alliance enterprises, customer orders must to transfer into manufacturing resources of the enterprises rapidly.

In recent years, many scholars have researched about manufacturing resources from resources optimization deployment, Job shop scheduling and the resources evaluation method etc. Many evaluation methods and algorithms were built[1-6].

On the basis of previous researches, this paper studied on the intelligent manufacturing resources of alliance enterprises. The resources were divided and analyzed. FAHP was used to evaluate the configuration of the resources. Then the evaluation server platform of manufacturing resources was established. On the platform, all of the resources of the alliance enterprises were unified, according to customer requirements, resources can be configured and deployed to satisfied with them.

2. Application of FAHP in Evaluation of Intelligent Manufacturing Resource Allocation

2.1 Characteristics and Classification of Manufacturing Resources in Alliance Enterprises
The classical manufacturing resources are all kinds of physical factor and resources in product manufacturing cycle life[7]. Now, information technology, network and new manufacturing technology...
refine manufacturing resource. Modern manufacturing resource is intelligent resource, which is all resources involved in the whole life cycle of internal products in an enterprise under intelligent manufacturing mode, using artificial intelligent, information technology, big data technology and manufacturing technology. According to customers different requirements, it can configure resource and service rapidly and efficiently, realizing enterprise reaction quickly.

Manufacturing resources of alliance enterprise can provide efficiently customer service combining all kinds of manufacturing resources on the alliance service platform. Alliance enterprise resources has the characteristics of dispersion and concentration, dynamic and static, repetition and unique, intelligence and diversity. How to combine and configure these manufacturing resources efficiently becomes the key for alliance enterprises to respond to the market quickly and meet the needs of customers. The typical characteristics of resources in alliance enterprises include as follows,

- Dispersion and concentration
  In industrial alliance, manufacturing resources belong to different enterprises. It is very scattered in the region. In the allocation of resources, we must go through the concentration of information and logistics distribution. But on the alliance enterprise service platform, during configuration and using according to customers requirement, the resources have the property of concentration.

- Dynamic and static
  Manufacturing resources have many properties not only including static characteristics such as size, color, chemical and so on, but also have some dynamic characteristics. These dynamic attributes include the processing status, the logistics status, and the usage status of the device resources, etc., where the manufacturing resource is located. Such as mechanical equipment shutdown, work, maintenance state and the like.

- Repetition and unique
  The resources in alliance enterprise have repetition in type. There is also repetition in the business associated with it. When different enterprises have the same resources which can meet the customers requirement, we need to evaluate resources and configure fairly. Once the resources are determined, it has unique property.

- Intelligence and diversity
  The resources have diversity because it belong to different enterprise and have large quantity and type. The main difference between the intelligent manufacturing and the traditional manufacturing mode is that the application of various advanced technologies makes the whole life cycle of the whole product have the intelligence, especially the intelligence of the manufacturing resource determines the manufacturing capability and the manufacturing level of the enterprise.

To sum up, the intelligent manufacturing resources of the alliance enterprises are different from the traditional manufacturing resources, and a more comprehensive and more systematic classification is needed. Intelligent manufacturing resources not only include traditional resources, but also have new characteristics under new technology environment. In the study of cloud manufacturing resources, the author divides the manufacturing resources into eight categories: manpower, collaboration, service, material, equipment, application, data and logistics resources\[^{8-9}\]. New resource should also include intelligent network resources. On the basis of Internet of things(IOT), big data and new computer technology, intelligent network resources combine the whole production cycle and IOT in manufacturing enterprises to control and manage all kinds of resources in the whole process, which can effectively reduce the redundancy and waste of resources and increase the interests of alliance enterprises. There are no strict boundaries for the classification of these resources, and the classification is adjusted dynamically according to the needs of enterprises and market changes.

2.2 Application of FAHP in the Evaluation of Manufacturing Resources

Fuzzy Analytic Hierarchy Process(FAHP) combines the advantage of Fuzzy evaluation method and AHP, which solves the problem that AHP thinking consistency is difficult to guarantee when there are too many evaluation indexes. The main idea and procedure are same to AHP. The main difference lies in the constructed judgment matrix and the weight method to solve the relative importance of each
element in the matrix. The key procedures of FAHP include: establishing the evaluation criterion of each layer, constructing the judgment matrix of each level, calculating the index weight of each layer, carrying on the consistency test, obtaining the index weight set, establishing the relative importance of the criterion, forming the fuzzy judgment matrix, and fuzzy comprehensive evaluation of manufacturing resources.

2.2.1. Building the manufacturing resource evaluation system of alliance enterprise
There are six evaluation indexes CIQLST for the target layer T of the evaluation system of manufacturing resources of alliance enterprises. The indexes are Cost, Intelligence level, Quality, Logistic, Service and Time. Every index can divide into sub-index S. There are 19 sub-indexes as shown in Figure 1.

![Figure 1. Hierarchical structure of manufacturing resource evaluation system of alliance enterprises.](image)

As shown in the Figure 1, S1-Managed cost; S2-Supplementary cost; S3-production cost; S4-Informatization; S5-Flexibility; S6-Integration; S7-Reliability; S8-Performance; S9-Safety; S10-Logistic route; S11-Logistic equipment; S12-Storage; S13-Service level; S14-Service response; S15-Service ability; S16-Service Content; S17-Process time; S18-Delivery time; S19-Setup time

The manufacturing resource evaluation of alliance enterprise is the target layer, which need to determine the resources that meet customer’s order and then rapidly deploy and produce. The evaluation index layer is used to judge the evaluation system of manufacturing resources. For example, the degree of intelligence, is the modern manufacturing resources unique evaluation criteria, can explain the degree of integration of the enterprise and IOT, big data and other advanced technology. This index can be divided into information level, flexibility level and integration level several sub-indicators.

| Scale | Comparison of two indicators | Explanation |
|-------|------------------------------|-------------|
| 1     | Equal importance            | Both elements are equally important |
| 3     | Slightly important          | One indicator is slightly more important than the other |
| 5     | Obvious importance          | One indicator is more important than another |
| 7     | Much more important         | One indicator is significantly more important than the other |
| 9     | Absolute importance         | One indicator is absolutely more important than the other |
| 2, 4, 6, 8 | Between two adjacent importance | Median value of two grade judgments |

2.2.2. Establishment of the weight of each evaluation factor of manufacturing resources
In order to calculate the importance of 19 factors in the sub-target layer of manufacturing resource evaluation system to intelligent manufacturing resource evaluation system, according to the historical experience data and expert consultation, based on Table 1, the pairwise comparison of each index is
carried out, and the judgment matrix of intelligent manufacturing resource evaluation index and each sub-index is constructed by using AHP.

For example, according to the relative importance of the six indexes of intelligent manufacturing resources to the target layer, the judgment matrix is constructed as follows:

\[
\begin{bmatrix}
1 & 1/4 & 1/3 & 2 & 1/2 \\
4 & 1 & 2 & 6 & 5 \\
3 & 1/2 & 1 & 5 & 4 \\
1/3 & 1/6 & 1/5 & 1 & 1/2 \\
1/2 & 1/5 & 1/4 & 2 & 1 \\
2 & 1/3 & 1/2 & 4 & 3 \\
\end{bmatrix}
\]

The judgment matrix of sub-target layer S to evaluation layer C is established in turn, and the weight calculation and consistency test are carried out. Finally, the weight of each target is obtained as shown in Table 2.

Table 2. Evaluation refers to a list of fine weight sets.

| Target layer | Indicator layer $W_c$ | Indicator item level $W_i$ |
|--------------|----------------------|---------------------------|
| Cost C(0.381) | Managed Cost S1(0.195)  |
|              | supplementary cost S2(0.232) |
|              | Production cost S3(0.573)  |
| Intelligence Level I(0.160) | Informatization S4(0.263) |
| Quality Q(0.252) | Reliability S7(0.135)   |
| Logistic L(0.064) | Performance S8(0.584)   |
|              | Safety S9(0.281)         |
| Service S(0.042) | Route S10(0.573)        |
|              | Equipment S11(0.232)     |
|              | Storage S12(0.195)       |
| Time T(0.101)  | Service level S13(0.133) |
|              | Service Response S14(0.088)|
|              | Serviceability S15(0.262)|
|              | Service content S16(0.517)|

2.2.3. Comprehensive evaluation of candidate manufacturing resources by FAHP

When a customer publishes the demand to the service platform, the alliance enterprise as the servicer responds quickly, gives the candidate manufacturing resource selection scheme, evaluates the candidate scheme which meets the requirements through the platform primary selection, and determines the final scheme for resource allocation and production, so as to realize the efficient utilization of resources and the win-win situation of the enterprise. According to the above analysis, FAHP is applied to comprehensively judge the candidate manufacturing resources which meet the needs of the customers, and the comprehensive weight value of the manufacturing resources on the target layer is calculated, and the optimal manufacturing resource candidate scheme is obtained. The formula are as follows:
\[ W = W_C W_T^T \]  
(1) 

\[ W_C = [W_{C1} W_{C1} ... W_{Cj}] \]  
(2) 

\[ W_{CI} = W_{Si} W_{SI} \]  
(3)

\( W_C \) is the weight vector of the index layer \( C \) to the target layer \( T \), \( W_S \) is the weight vector of each sub-index \( S \) to the evaluation index layer \( C \). \( W_{CI} \) is the relative importance of each sub-index in each candidate scheme. And the weight value in the judgment matrix can be calculated by means of a root method. Then the optimal manufacturing resource candidate scheme is obtained according to the calculation result, and the basis of the high-efficiency utilization of the subsequent resources is provided.

3. Evaluation Service System of Manufacturing Resource Allocation in Alliance Enterprises

This system design and procedure by VB6.0, which has function module about inputting the intelligent manufacturing resource information, weight calculation of evaluation criterion, evaluating several candidate resource etc. According to the above evaluation architecture, the weight calculation results of manufacturing resources are obtained on the basis of expert scoring, and the dynamic evaluation index weight set is obtained by root finding method. As shown in Figure 2. In the candidate scheme evaluation module, the expert evaluates several candidate schemes, obtains the fuzzy evaluation matrix, and processes the data according to the algorithm in turn. In the process of calculation, the system will test the consistency of each judgment matrix, compare the different manufacturing resources and obtain the evaluation results.

![Figure 2. Weight calculation of evaluation index of manufacturing resources.](image)

According to the above evaluation architecture, the manufacturing resources obtain the weight calculation results on the basis of expert scoring, and use the root finding method to get the dynamic evaluation index weight set. as shown in Figure 3. In the candidate scheme evaluation module, experts rate several candidate schemes for index evaluation, obtain fuzzy evaluation matrix, and process the data according to the algorithm in turn. In the calculation process, the system will check the consistency of each judgment matrix, compare the different manufacturing resources and obtain the evaluation results. Taking two candidate schemes for evaluation analysis as an example, the final evaluation results are obtained, and the partial interface is shown in Figure 3.

![Figure 3. Candidate manufacturing resource evaluation system.](image)
4. Conclusion
With the continuous implementation of intelligent manufacturing 2025 in China, the equipment manufacturing industry is facing more and more severe competition and test. It is necessary to deal with the rapid development of global manufacturing industry, the continuous updating of various information technology, manufacturing technology, network technology, and the continuous improvement of customer requirements. The emergence of industrial alliance provides a way out for the survival of some small and medium-sized enterprises. Good industry alliance service platform, fast response to the market and provide services of alliance enterprises, to meet service needs of customers to form a win-win situation. It is of great significance to study the allocation scheduling and evaluation of manufacturing resources under the industrial alliance, which provides a strong basis for the efficient utilization of resources.

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