Evaluation of Aerospace Production Site Management and Control Capability based on F-AHP and BP Neural Network

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Abstract. The management and control level of aerospace production site directly affects the production quality of aerospace products. It is one of the important fields of aerospace quality management research to master the management and control ability of aerospace production site efficiently. Based on the analysis of the control scope of aerospace production site, the evaluation index system of space production site control ability is proposed. Through the establishment of Fuzzy-Analytic Hierarchy model, the sample data of process management and control ability evaluation on aerospace production site was collected. BP neural network model was constructed and trained, the output of BP neural network reached the expected accuracy, which meet the requirements of process management and control ability evaluation on aerospace production site. The result shows that the proposed evaluation index system and BP neural network model can not only fully absorb the tacit knowledge of experts, but also reduce the subjective arbitrary defects of artificial weights, which can be used to evaluate of the control ability of aerospace production site efficiently.

1. Introduction

Aerospace production site management and control is an important field of aerospace quality management and a key link to ensure the quality of aerospace products and improve their production efficiency. In recent years, with the rapid growth of aerospace production missions, low-level problems such as human error operation, chaotic use of documents, mixing of unqualified products and electrostatic introduction have been exposed in the production process of aerospace products, which have caused certain hidden dangers to the quality of aerospace products and thus affected the success or failure of aerospace missions. It is an important way to effectively evaluate the quality control ability of the aerospace production site and identify the weak links in the aerospace production site management and control. Meanwhile, with the deepening of civil-military integration in the aerospace field, more and more private enterprises are involved in the production of aerospace products. However, the refined quality management of aerospace products has a high requirement for process control. It is the key field of current aerospace production quality management to evaluate the control ability of production sites participating in aerospace production tasks reasonably and efficiently and to strictly control access regulations of production sites which participating in research.

At present, there have been some studies about production site management and control. Xing proposed a collaborative production process management method of purchased material for complex product assembly, and realize the collaborative management and control of purchased material production process [1]. Jia proposed the process control measures of quality problem close-loop based
on process document, achieving standardized management of quality problems in the production process [2]. Gao proposed a practical solution which offers professional reference production frame and model to help the enterprise building a balanced, transparent and effective production management system [3]. Zheng analysed the production control technology from the unit manufacturing equipment and process optimization, and proposed the future works in the field [4]. However, the above studies are focused on a specific link in the production process, and there is a lack of research on the evaluation of the overall management and control capabilities of the production process.

In order to effectively evaluate the aerospace production site management and control ability, this paper constructs a aerospace production site management and control model from the perspective of process control, and proposes an index system for evaluating the aerospace production site management and control ability. A data acquisition model was constructed by F-AHP, and the expert scoring method was used to collect sample data for the evaluation of the control ability of the aerospace production site. The BP neural network was constructed, and the sample data was used to train the neural network, and a neural network model that could be used to evaluate aerospace production site management and control ability was obtained. It can promote the implementation of efficient evaluation of aerospace production site management and control ability.

2. Research the evaluation index system of process control

2.1. Aerospace production site control scope

Aerospace production site control is to use systematic methods to plan, control and improve the product production process, so as to promote the high quality and high efficiency of aerospace product production. The space production site control is mainly the control of the production process of aerospace products. The process is a set of interrelated or interacting activities that convert inputs into outputs [5].

The task of a process is to convert valid inputs into expected outputs. Effective input requires not only correct direction guidance, but also scientific systematic planning. The site control needs to be pushed forward by senior leaders, setting reasonable production targets, providing corresponding resource guarantee. System planning is after determine the direction and obtain resources, the transformation executive to ensure the effective implementation of the transformation, make the corresponding planning arrangements, identify potential risks, etc. Transformation is a process execution activity. In order to ensure the effective and reasonable transformation, the execution activities related to the aerospace production process should be strictly controlled to meet the planning requirements.

The expected output needs to be judged by inspection, from the aspects of quality conformity, method advancement, operation adaptability, program efficiency, etc. The improvement is required If somewhere needs to be improved.

2.2. Construct evaluation index system

2.2.1. Propose the construction principle of evaluation index system. In order to ensure the comprehensive and reasonable evaluation index system of aerospace production site management and control capacity was constructed, the construction principles are proposed:

(1) Principles of system decomposition. The evaluation of aerospace production site management and control capacity is a complex problem with multiple elements. It is decomposed into different components (namely, evaluation dimension), refined and decomposed into specific evaluation indexes according to the content relation of evaluation dimension, and the evaluation index system is constructed from top to bottom through systematic classification and layer by layer decomposition.

(2) Principles of full application. The construction of evaluation index system should start from the overall situation and comprehensively consider various factors such as human, machine, material,
method, environment and measurement, so as to comprehensively identify the factors affecting the process control ability of the aerospace production site and convert them into specific evaluation indexes, which are generally applicable to the process control ability evaluation of the aerospace production site.

(3) The principle of comprehensive coordination. The evaluation dimensions should be clearly classified to avoid cross repetition, and the set of evaluation dimensions should be coordinated with the evaluation objectives. At the same time, the evaluation indexes should reflect the content requirements of the evaluation dimension, the evaluation indexes of the same evaluation dimension should be interrelated and avoid duplication. And the set of all the evaluation indexes of the same dimension should be coordinated with the requirements of the evaluation dimension.

2.2.2. Categorize and propose evaluation dimensions. According to the control scope of aerospace production site, the aerospace production site management and control stage can be divided into four dimensions, including organization and promotion, process planning, process implementation, monitoring and improvement.

Organization and promotion is the basis of effective space production site process control. Aerospace production site process control not only needs the effective implementation of the production site staff, but also needs the decision support of senior leaders, is a comprehensive management work. Organization and promotion not only indicate the direction of process control on the production site, but also provides the resources for process control, which directly affects the level of control on the production site. The organization and promotion mainly provide the goals and resources of the process control of the aerospace production site.

Process planning is the starting point of effective aerospace production site process control. Process planning provides input requirements for aerospace production tasks, and its work quality directly affects the effect and efficiency of aerospace production site process control, thus affecting the ability level of aerospace production site process control. Process planning mainly evaluates the aerospace production site planning, risk identification, site layout, document formulation and release, etc.

Process implementation is the core of process control in aerospace production site. According to the results of process planning, advanced quality management tools, methods or measures shall be adopted to control all elements related to aerospace production activities in an orderly manner, so as to ensure the orderly development of all production activities on the space production site. Process implementation mainly evaluates the implementation norms of relevant control activities and control measures taken at the aerospace production site.

Monitoring and improvement is an important activity to ensure the continuous improvement of process control capacity in aerospace production sites. Through effective monitoring of the implementation results of the aerospace production site process, timely detection of hidden dangers, scientific decision making, correction of existing problems, continuous improvement and optimization, continuous improvement of the aerospace production site process management and control capacity. Monitoring and improvement mainly evaluates the control situation of process monitoring, measurement, deviation correction and other aspects of the aerospace production site, as well as the implementation of optimization, improvement, innovation and other aspects.

2.2.3. Refine and propose evaluation index system. According to the requirements of evaluation dimension and combined with the process management and control activities in the aerospace production and production site, the contents of management and control of evaluation dimension are refined. The evaluation index system is summarized and proposed, as shown in Figure 1.
2.2.4. Propose the content requirements of each evaluation index. The national standards, aerospace industry standards, aerospace enterprise standards, and aerospace quality management requirements related to each evaluation index are systematically analyzed. The content requirements of each evaluation index are studied and proposed in combination with the process control characteristics of aerospace production site, so as to facilitate the collection of relevant evaluation index data and promote efficient evaluation. When making the description of the content requirements of the evaluation index, it shall be arranged according to the execution sequence or implementation logic of the content on the production site. Considering the limitation of space, the paper takes "risk identification and prevention" as an example to explain the content requirements of evaluation index. It is shown in Table 1.

| Evaluation index                  | Content requirements                                                                                                                                                                                                 |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Risk identification and prevention | It mainly evaluates the comprehensive identification of risks related to on-site production activities and the implementation of prevention, in line with relevant standards or documents. |
|                                   | ① The production site identified the production activities in the relevant risk points, the implementation of aerospace products risk identification and control requirements;                                   |
|                                   | ② The production site developed the risk analysis and control of the relevant standards or requirements, clear the responsibility and boundaries of risk control;                                                              |
|                                   | ③ For the potential risks in the production process, the production site takes corresponding preventive measures and control measures to achieve preventive management.                                                                 |

**Figure 1.** Evaluation index system of aerospace production site management and control capacity.
3. Evaluation model of aerospace production site control capability

3.1. Establish a set of evaluation criteria
The evaluation standard set of aerospace production site management and control capability includes evaluation index standard set and management and control capability evaluation grade standard set.

Establish a standard set of evaluation indicators:
The evaluation index standard set \( V \) is the evaluation index grade standard set, which is divided into 4 grades. \( V = \{ \text{excellent, good, qualified, unqualified} \} \).

Evaluation index data of aerospace production site management and control are obtained from expert scores. In order to ensure the reasonable and scientific evaluation of aerospace production site management and control ability, the fuzzy quantitative evaluation is adopted to standardize the data collection of evaluation index. In order to avoid absoluteness of evaluation index data, the fuzzy scores of adjacent evaluation indexes are overlaps. The fuzzy data of evaluation index is shown in Table 2.

| Index level | Excellent | Good | Qualified | Unqualified |
|-------------|-----------|------|-----------|-------------|
| Score range | 1.0, 0.95, 0.9 | 0.75, 0.8, 0.85, 0.9 | 0.6, 0.65, 0.7, 0.75 | 0.2, 0.4, 0.6 |

Each aerospace production site corresponds to 18 corresponding evaluation indexes, and each evaluation index corresponds to a specific evaluation fuzzy data, which is used as the data input of the evaluation index.

The standard set \( U \) of aerospace production site management and control capability level is a collection of evaluation results made by evaluators on evaluation indicators. The capability level is divided into 4 levels, \( U = \{ \text{excellent, good, medium, poor} \} \).

In order to carry out effective calculation, the evaluation level will be quantified and a corresponding scoring range will be set for each evaluation level, which is shown in Table 3.

| Ability level | Excellent | Good | Medium | Poor |
|---------------|-----------|------|--------|------|
| Score range   | [0.9, 1.0] | [0.75, 0.9] | [0.6, 0.75] | (0, 0.6) |

Each aerospace production site corresponds to one evaluation capability score, which is output as for the evaluation of the on-site management and control capability.

3.2. Sample data collection
Sample data is the key to the successful training of BP neural network model. The comprehensiveness and rationality of sample data directly affect the accuracy of evaluation results.

The sample data consists of two parts, indicator sample data and capability sample data. Evaluation index data are collected by means of expert scoring. Capability sample data is the result of comprehensive calculation of index sample data.

To ensure the objectivity of expert evaluation, \( k \) experts from different fields of production management and quality management in the aerospace field were selected to evaluate each pilot production site respectively. Each expert constructed the score function of control ability by analytic hierarchy process (AHP) and calculated the corresponding sample ability data based on the collected index sample data.

Each expert independently evaluates each pilot production site to obtain a sample set of evaluation data for each pilot production site. In order to avoid subjective randomness by experts, if the
difference between two identical indicators on the same site is greater than 0.2, the corresponding sample data is eliminated.

There are \( h \) aerospace production sites selected for pilot evaluation, and the evaluation index sample data set \( C \) and control ability score data set \( A \) were obtained.

\[
C = \begin{bmatrix}
C_{1-1} & C_{1-2} & \ldots & C_{1-43} \\
C_{2-1} & C_{2-2} & \ldots & C_{2-43} \\
\vdots & \vdots & \ddots & \vdots \\
C_{h-1} & C_{h-2} & \ldots & C_{h-43}
\end{bmatrix}, \quad A = (A_1, A_2, \ldots, A_{t})^T
\]

\[(1)\]

3.3. Construct BP neural network model

The BP neural network is composed of an input layer, hidden layer, and an output layer. It is a multi-layer feedforward neural network trained according to the error back propagation algorithm. It consists of two processes, signal forward propagation and error back-propagation. The collected evaluation index sample data is input by the input layer, processed by the hidden layer, and the evaluation result is output by the output layer. If the gap between the evaluation output and the sample result is large, the error back-propagation process is carried out, starting from the output layer, correcting the weights of each layer, and sequentially propagating to the hidden layer and the input layer [6]. Through continuous forward propagation and back-propagation, after multiple training and learning, until the evaluation result error is reduced to an acceptable level, the training is over.

(1) Construction of BP neural network structure

Construct a BP neural network with input layer, hidden layer and output layer. Both the input layer and the output layer are one layer. The number of BP neural network hidden layers needs to be defined.

The number of hidden layers is small, and the structure of the BP neural network is simple, which can achieve fast training, but it will also lead to lower accuracy. There are many hidden layers, which can improve the training accuracy, but the BP neural network has a complicated structure and a long training time [6]. According to the proposed standard set of capability levels, the score range between different standard levels is large, which allows a relatively large error range between the evaluation output of the BP neural network and the sample results. Considering the fact that many hidden layers are easily trapped in local minima and difficult to train. In this paper, one hidden layer is selected to construct a three-layer BP neural network composed of "input layer-hidden layer-output layer".

(2) Define the number of neurons in each layer

The evaluation index of the management and control capability of the aerospace production site is the input of the BP neural network. The number of neuron nodes in the input layer should correspond to the evaluation index. The number of input layer nodes of the BP neural network is \( p=18 \).

The output layer is a response to the input signal. Each production site corresponds to a specific evaluation capability score. The number of output layer nodes of the BP neural network is \( t=1 \).

There is currently no unified method for defining the number of hidden layers, which generally depends on empirical formulas. Use empirical estimation formula \( m = \sqrt{p + t + n} \) (Where \( p \) is the number of the input layer nodes, \( t \) is the number of the output layer nodes, and \( n \) is a constant that is between 0 and 10) [7], combined with human experience, the number of hidden layer nodes is comprehensively determined, and the average relative error after training is 2.55%.

Use empirical formula \( m = \sqrt{0.43pt + 2.54p + 0.77t + 0.35} + 0.51 \) (where \( p \) is the number of the input layer nodes, \( t \) is the number of the output layer nodes) with trial and error method to determine the number of hidden layer nodes [8], the minimum error after training is 0.15%.

An improved golden section method is proposed to determine the number of hidden layer nodes [9], and the error after training was less than 1%.

Based on comparative analysis, the average error of golden section method is smaller than that of empirical estimation method, and it has a more optimized network model. Therefore, the golden section method is chosen as the method to define the number of hidden layer nodes.
Use formula \( x = \frac{p + t}{2} \leq m \leq (p + t) + 10 = y \) (where \( p \) is the number of input layer nodes, \( t \) is the number of the output layer nodes, and \( m \) is the number of the hidden layer nodes). The initial range of nodes in the hidden layer is defined as \([9, 29]\), and the error size of nodes in different hidden layers is calculated by using the sample data of the test.

First, determine the location of the first test point (Golden Section 1) \( g_1 = 0.618 \times (y - x) + x \), and record the error result \( \sigma (g1) \) of the first test point. (Where, \( \sigma (g1) \) is the training error when the hidden layer node is \( g1 \)).

Secondly, determine the location of the second test point (golden section point 2) \( g_2 = 0.382 \times (y - x) + x \), record the error result as \( \sigma (g2) \).

Again, compare the error between the two results. If \( \sigma (g1) < \sigma (g2) \), it means that the result of \( g1 \) is better, leave \([g2, y]\), remove \([x, g2]\); otherwise, leave \([x, g1]\) and remove \([g2, y]\); if they are equal, leave \([g2, g1]\).

Finally, repeat the above experiment to find the ideal number of hidden layer nodes (the number of nodes corresponding to the minimum value of the mean square error in all nodes), which is the number of hidden layer nodes of BP neural network.

(3) Select training algorithm
Considering the wide range of evaluation indicators and the large number of sample data, in order to avoid the problem of BP neural network falling into local minimization or too long training time during the training process, an adaptive learning rate with momentum gradient descent algorithm is adopted to train the BP neural network.

In BP neural network training, the adaptive learning rate with momentum gradient descent algorithm combines the advantages of the adaptive learning algorithm and the momentum algorithm. The momentum gradient descent algorithm mainly affects the current correction amount through the previous correction result, ensuring that the direction of correction is toward the direction of convergence, which can not only ensure convergence, but also reduce learning time [6]. The adaptive learning algorithm that the learning rate can be dynamically adjusted according to the local error surface in the training process, which is not only to ensure the stability of the algorithm, but also can accelerate the convergence rate.

4. Construct F-AHP model and obtain sample data
The F-AHP method is adopted to construct the sample data acquisition model and collect the sample data effectively with the help of expert scoring.

4.1. Define weight
4.1.1. Build weight priority relationship function. The process control capability of the aerospace production site is composed of 4 dimensions, and each dimension is composed of corresponding evaluation indicators. Before collecting sample data, it is necessary to separately judge the weight of the evaluation dimension and the evaluation indicators under the same evaluation dimension. The evaluation index weight priority relationship function established is (Among them, \( C_i \) and \( C_j \) are evaluation indexes):

\[
f(ij) = \begin{cases} 
4.00, & C_i \text{ is extremely stronger than } C_j \\
2.00, & C_i \text{ is slightly stronger than } C_j \\
1.00, & C_i \text{ is equivalent to } C_j \\
0.50, & C_i \text{ is slightly weaker than } C_j \\
0.25, & C_i \text{ is extremely weaker than } C_j 
\end{cases}
\]  

(2)
4.1.2. Construct the judgment matrix of evaluation dimension. According to the constructed weight priority relationship function, the weight judgment matrix of the evaluation dimension is constructed, and the importance of each evaluation dimension to the process control capability \( A \) of the aerospace production site is calculated.

The evaluation dimension judgment matrix \( B^k_i \) constructed by expert \( k \) is:

\[
B^k_i = \begin{bmatrix}
 b_{11}, b_{12}, b_{13}, b_{14} \\
 b_{21}, b_{22}, b_{23}, b_{24} \\
 b_{31}, b_{32}, b_{33}, b_{34} \\
 b_{41}, b_{42}, b_{43}, b_{44}
\end{bmatrix}
\]

among them, \( b_{ij} > 0, b_{ii} = 1, b_{ij} = \frac{1}{b_{ji}} \quad (i, j = 1, 2, 3, 4) \) \hspace{1cm} (3)

Calculate the importance of each evaluation dimension \( B_i \) to the process control capability \( A \) of the aerospace production site. Based on the constructed judgment matrix, the expert \( k \) gives the index importance \( b^k_i \) of the evaluation dimension as: \( b^k_i = \prod_{j=1}^{4} b_{ij}^{rac{1}{4}}, (i, j = 1, 2, 3, 4) \).

The weight of each evaluation dimension \( B \) for the process control capability \( A \) is normalized to determine the weight of each evaluation dimension. The weight \( \bar{b}_i \) of the evaluation dimension constructed by expert \( k \) is:

\[
\bar{b}_i = \frac{b^k_i}{\sum_{i=1}^{4} b^k_i}, (i = 1, 2, 3, 4)
\]

After normalization, the weight vector \( \bar{b}_1, \bar{b}_2, \bar{b}_3, \bar{b}_4 \) of the evaluation dimension is obtained.

After the weights are initially defined, a consistency test is performed. After the consistency test requirements are met, it can be used to calculate the score of the management and control capability after sample data collection.

4.1.3. Construct a judgment matrix of evaluation index to determine the weight of evaluation index. Construct the evaluation index weight judgment matrix under each evaluation dimension, and calculate the weight of each evaluation index under the evaluation dimension.

For the evaluation dimension \( B_i \) (\( i = 1, 2, 3, 4 \)), the index importance of expert \( k \) is \( c^k_{ij} \) in the evaluation dimension (\( j \) is the corresponding number of evaluation indexes in each evaluation dimension).

The weight of each evaluation index \( C \) for the evaluation dimension \( B \) is normalized, and the weight of each evaluation index in the evaluation dimension is determined. The expert \( k \) calculates the evaluation dimension \( B_i \) (\( i = 1, 2, 3, 4 \)) The weight \( c^k_{ij} \) of each evaluation index under.

After initially defining the weights, a consistency test is performed, and after meeting the consistency test requirements, it can be used to calculate the score of each evaluation dimension in sample data collection.

4.2. Construct a score function for management and control capabilities

4.2.1. Score function \( B_i \) of evaluation dimension. According to the weights of all evaluation indicators in each evaluation dimension, the evaluation function \( B \) to construct the evaluation dimension is:

\[
B_i = f(C_{i1}, C_{i2}, \ldots, C_{ij}) = \sum c_{ij} \cdot C_{ij}
\]

\hspace{1cm} (4)
Among them, \( c_{ij} \) is the weight of the evaluation index in the evaluation dimension, and \( c_{ij}+c_{i2}+\ldots+c_{ij}=1 \). \( C_j \) is the actual score value of the evaluation index by experts.

4.2.2. Scoring function \( A \) of management and control ability. The aerospace production site process control ability is composed of four dimensions, organization and promotion, process planning, process implementation, monitoring and improvement. The scoring function \( A \) of the space production site process control ability is:

\[
A = f(B_1, B_2, B_3, B_4) = \sum_{i=1}^{4} b_i \cdot B_i \tag{5}
\]

Among them, \( b_1, b_2, b_3, b_4 \) are the weights corresponding to organizational and advancement, process planning, process implementation, monitoring and improvement, and \( b_1+b_2+b_3+b_4=1 \). \( B_1, B_2, B_3, B_4 \) are the actual score data of organizational and advancement, process planning, process implementation, monitoring and improvement, that are obtained according to the fuzzy hierarchical evaluation function of the evaluation dimension.

4.3. Conduct trial evaluation to obtain sample data

4.3.1. Collect sample data from each production site. Select experts in the fields of production management, quality management, etc. in the aerospace field to form an expert group, score the index through field evaluation, and collect sample data of each evaluation index. Each expert calculates the management and control ability score of the production site according to the management and control ability score function constructed by himself.

In order to avoid the interference of individual data on the sample results, for different expert data of the same evaluation index in the same production site, if the difference between the maximum value and the minimum value is greater than 0.2, the corresponding data is eliminated.

4.3.2. Collect and form sample data set. There are 20 production sites engaged with different businesses in the aerospace field selected as pilot sites to collect sample data of evaluation index and sample data of management and control capability scores. After cleaning, sorting and randomizing the sample data of each production site, a sample data set with 80 samples was collected comprehensively. Considering the space limitation, some sample data contents are shown, as shown in Table 4.

| No. | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C19 | C20 | C21 | C22 | C23 | C24 | C25 | C26 | C27 | C28 | C29 | C30 | C31 | C32 | C33 | C34 | A  |
|-----|----|----|----|----|----|----|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1   | 0.8| 0.8| 0.8| 0.8| 0.7| 0.8| 0.8| 0.8| 0.7| 0.8| 0.7| 0.8| 0.8| 0.8| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7 |
| 2   | 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9 |
| 3   | 0.8| 0.8| 0.8| 0.8| 0.7| 0.8| 0.8| 0.7| 0.7| 0.8| 0.8| 0.8| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7 |
| 4   | 0.7| 0.7| 0.7| 0.7| 0.6| 0.7| 0.7| 0.7| 0.7| 0.6| 0.7| 0.6| 0.6| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7 |
| 5   | 0.8| 0.8| 0.7| 0.8| 0.8| 0.8| 0.8| 0.7| 0.8| 0.8| 0.7| 0.8| 0.8| 0.8| 0.7| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8| 0.8 |
| 6   | 0.6| 0.6| 0.6| 0.6| 0.4| 0.4| 0.4| 0.4| 0.4| 0.6| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4| 0.4 |
| 7   | 0.9| 0.9| 0.9| 0.9| 0.8| 0.8| 0.8| 0.8| 0.9| 0.9| 0.8| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9 |
| 8   | 0.8| 0.8| 0.8| 0.8| 0.7| 0.7| 0.7| 0.7| 0.8| 0.8| 0.8| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7| 0.7 |
| 9   | 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9| 0.9 |

Table 4. The sample data set.
5. Case analysis

5.1. Define the number of hidden layer nodes

According to the evaluation index system of aerospace production site management and control capability, the input layer node number \( p = 18 \) of the defined BP neural network and output layer node number \( t = 1 \).

The number of hidden layer nodes is defined by the “golden section method”. After the BP neural network converges, iterative times and mean square errors of networks with different number of nodes are compared, and the number of nodes corresponding to the optimal neural network is selected as the number of nodes in the hidden layer. Set the target mean square error to 0.01. After calculating by the “golden section point method”, iteration times and mean square error of different networks are obtained. After three rounds of golden section point calculation, the result shows that the performance of each BP neural network has reached the established requirements. When the number of hidden layer nodes is 21, the mean square error and the number of iterations are the smallest. Therefore, the number of hidden layer nodes is chosen to be 21.

5.2. Training sample data

Through the construction of fuzzy analytic hierarchy process, 80 samples of data were collected. Among them, 60 samples were selected as training samples, and the remaining 20 samples were used as test samples for BP neural network testing.

Using Matlab for BP neural network training, the results show that the BP neural network reaches the set precision requirements after 11 iterations, and the training can be stopped in a short time. The training result of BP neural network is shown in Figure 2; the comparison between training sample data and learning result is shown in Figure 3.
Figure 2. Result of BP network training.

Figure 3. Comparison between training sample data and learning result.

It can be seen from Figure 2 that the ideal regression line (dashed line in the figure) and the optimal regression line (straight line in the figure) basically coincide. Figure 3 shows that the maximum error between the expected result of the training sample data and the training result does not exceed 0.01, which meets the accuracy requirements.

After the BP neural network training is completed, the test sample data is used to detect the BP neural network. Use the trained BP neural network to obtain the data result of the test index data, and compare the error between the run output value and the actual evaluation result. The result is shown in Table 5, and the maximum error is 0.0265, indicating that as long as the input data is accurate and reasonable, the obtained BP neural network model can get relatively accurate evaluation results.

| Test sample | 61  | 62  | 63  | 64  | 65  | 66  | 67  | 68  | 69  | 70  |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Run output  | 0.6973 | 0.9023 | 0.8175 | 0.9033 | 0.8462 | 0.7162 | 0.8033 | 0.8907 | 0.8000 | 0.7990 |
| actual result | 0.697 | 0.900 | 0.814 | 0.900 | 0.848 | 0.715 | 0.803 | 0.890 | 0.802 | 0.791 |
| Relative error | 0.0003 | 0.0023 | 0.0038 | 0.0033 | - | 0.0018 | 0.0012 | 0.0008 | 0.0005 | - 0.0022 | 0.0078 |

Table 5. The relative error of test samples.
6. Conclusion

Aerospace production site management and control is a comprehensive management activity. Efficiently understanding the level of aerospace production site management and control is one of the important tasks of aerospace quality management. Firstly, the scope of management and control of the aerospace production site is analysed, the evaluation dimension and related activities of the aerospace production site management and control are proposed, the evaluation index system for the aerospace production site management and control evaluation is constructed, and the content requirements of evaluation index is defined. Secondly, an evaluation method combining fuzzy analytic hierarchy process and BP neural network is established, in view of the characteristics of many related factors of the aerospace production site management and control activities and the difficulty of obtaining data. The implementation process and key technical contents of the evaluation method are proposed. Thirdly, the F-AHP method is adopt to propose a sample data collection method, and sample data collection is collected to form a credible sample data set. Finally, through the construction and training of the BP neural network, the error between the training value and the actual value is compared. The results show that the evaluation model established can combine the advantages of F-AHP and BP neural network, which can support aerospace quality management personnel to effectively obtain credible index data, and use the trained BP neural network model to obtain the evaluation ability score efficiently. It can promote to determine the capability level of the aerospace production site management and control, avoiding the cumbersome calculation and subjective randomness of manual weighting.

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