Health Management Quality Assessment Of Complex Communication System

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Abstract. In order to verify the quality of health management of communication system and determine the application of health management in the field of communication system, the quality evaluation method is used to verify the operation effect. According to the analysis of the main functions and components of complex communication system health management, the evaluation index system is constructed, and the steps of quantitative evaluation of the evaluation index system by grey analytic hierarchy process are elaborated in detail. Combined with an example, the feasibility and rationality of the model algorithm are verified. The example proves that the evaluation results of health management quality of complex communication system based on grey analytic hierarchy process are accurate and feasible, which can provide direction and basis for the development of health management in communication field.

1. Introduction

In recent years, with the improvement of science and technology level and manufacturing process, complex communication systems tend to develop in the direction of high integration, high precision and strong integration. The internal structure of complex communication systems is becoming more and more complex, and problems such as difficult fault location and high maintenance cost are becoming increasingly prominent. Traditional maintenance support mode has been difficult to meet the development needs of current complex communication systems. Health management of complex communication system takes the health status of communication equipment as the maintenance base point, and meets the needs of maintenance and development of complex communication system through technical functions such as health status grading judgment, fault prediction and fault diagnosis. Compared with traditional maintenance support, the advantages of health management of complex communication system are as follows: accurate fault diagnosis and positioning, reasonable decision-making of auxiliary maintenance, accurate prediction of remaining life, etc. In the future, the deeper application of health management in the field of complex communication systems has become a major
trend. Under this background, it is necessary to evaluate the quality of complex communication system health management.

2. Analysis of the evaluation index system of complex communication system health management quality

The evaluation of health management quality of complex communication system is a complex and huge system engineering. To effectively evaluate the health management quality of complex communication system, an objective, effective and feasible evaluation index system should be established first.

Comprehensive analysis of the influencing factors on the health management quality of complex communication systems, its evaluation index hierarchy model can start from four influencing factors: key fault diagnosis, remaining life prediction, health status assessment and health information management. Using AHP, the evaluation index system can be divided into the hierarchical structure as shown in Figure 1.

![Figure 1. Hierarchical index system of health management quality evaluation of complex communication system](image)

3. Complex Communication system health management quality assessment process

Grey analytic hierarchy process (AHP) is a method which uses grey theory to deal with uncertain factors and analyze them on the basis of establishing evaluation index system and obtaining index weights by AHP, and then comprehensively calculates the evaluation value of the system.

3.1. Construct judgment matrix and calculate index weight

According to the hierarchical index system in Figure 1, the following settings can be made:

Middle tier indicator set: \( U_i = \{U_1, U_2, U_3, U_i\} \) (1)

The lowest index set is recorded as: \( U_{ij} = \{U_{1j}, U_{2j}, \ldots, U_{ij}\} \) \( i,j = \{1,2,3,4\} \) (2)

The intermediate index weight set is recorded as: \( W = \{W_1, W_2, W_3, W_4\} \) (3)

The lowest index weight set is recorded as: \( W_{ij} = \{a_{i1}, a_{i2}, \ldots, a_{ij}\} \) (4)

Among them, \( A_i \) is the weight value of standard layer indicator \( U_i \), and \( a_{ij} \) is the weight value of scheme layer indicator \( W_{ij} \), and they all have:

\[
A_i \in [0,1]; a_{ij} \in [0,1]; \sum_{i=1}^{4} A_i = 1; \sum_{j=1}^{4} a_{ij} = 1
\]

By comparing the importance of the lowest index to the middle layer criterion by experts, the judgment matrix is constructed, and the combination weight of the lowest index to the middle layer is calculated. See Table 1 below for the evaluation criteria of importance.
Table 1. Importance scoring criteria.

| Importance grade | Most important | Very important | Generally important | As important |
|------------------|----------------|----------------|---------------------|-------------|
| Comparison score | 1              | 2              | 3                   | 4           |

Here, taking $U_1$ as an example, the judgment matrix of $U_1$ is obtained through importance comparison as follows:

$$U_1 = \begin{bmatrix} 1 & \frac{4}{5} & \frac{3}{4} & \frac{4}{5} \\ \frac{5}{3} & 1 & \frac{3}{5} & \frac{3}{5} \\ \frac{5}{4} & \frac{4}{3} & 1 & \frac{3}{4} \\ \frac{5}{4} & \frac{4}{3} & \frac{3}{5} & 1 \end{bmatrix}$$

(6)

The eigenvector of $U_1$ is $w_2 = (a_{11}, a_{12}, a_{13}, a_{14})$

3.2. Develop evaluation index scoring standards

According to the evaluation standard of health management quality, the scoring standard can be divided into four grades: "excellent, good, moderate and poor", and the scoring standard is shown in Table 2 below.

Table 2. Scoring criteria

| Grading grade | Excellent | Good | Moderate | Bad |
|---------------|-----------|------|----------|-----|
| Scoring value | $10 \geq d > 8$ | $8 \geq d > 6$ | $6 \geq d > 4$ | $4 \geq d$ |

3.3. Determine the evaluation sample matrix

Arrange $k$ experts ($k=1, 2 ...$) to score the evaluation items according to the scoring standard in Table 2, and the $k$th expert scores $U_{ij}$ as $D_{ijk}$. By synthesizing the scores of $D_{ij}$ by $k$ experts, the scoring matrix can be obtained:

$$D_k = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1k} \\ d_{21} & d_{22} & \cdots & d_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nk} \end{bmatrix}$$

(7)

3.4. Determine and evaluate ash types

Determining the evaluation grey class means determining the grade number, grey number and whitening weight function of the evaluation grey class. According to the grading standards for the health management quality of complex communication systems defined above, the grey categories of comprehensive evaluation of health management of complex communication systems can be divided into four categories, and the grey number pairs should be excellent, good, moderate and poor, and the corresponding whitening weight functions are as follows:

The first grey class is "excellent" ($e=1$), that is, the grey number is $1 \in [0, 9, +\infty)$, and the corresponding whitening weight function is:
As shown in Figure 2

\[ f_i(d_y) = \begin{cases} 
\frac{d_y}{9} & d_y \in [0,9] \\
1 & d_y \in [9, +\infty] \\
0 & d_y \not\in [0, +\infty] 
\end{cases} \]  

(8)

Figure 2. The first gray whitening weight function

The second grey class "good" (e=2), that is, the grey number 2 \( \in [0,7,14] \), and the whitening weight function corresponding to the grey number is:

\[ f_2(d_y) = \begin{cases} 
\frac{d_y}{7} & d_y \in [0,7] \\
2 - \frac{d_y}{8} & d_y \in [7,14] \\
0 & d_y \not\in [0,14] 
\end{cases} \]  

(9)

As shown in Figure 3:

Figure 3. The second gray whitening weight function

The third gray class "Zhong" (e=3), that is, the gray number 3 \( \in [0,5,10] \), and its corresponding whitening weight function is:

\[ f_3(d_y) = \begin{cases} 
\frac{d_y}{5} & d_y \in [0,5] \\
2 - \frac{d_y}{4} & d_y \in [5,10] \\
0 & d_y \not\in [0,10] 
\end{cases} \]  

(10)

As shown in Figure 4:

Figure 4. The third gray whitening weight function

The fourth grey class "difference" (e=4), i.e. grey number 4 \( \in [0,3,6] \), and its corresponding whitening weight function is:
As shown in Figure 5:

\[ f_i (d_{ij}) = \begin{cases} 
1 & d_{ij} \in [0, 3] \\
2 - \frac{d_{ij}}{3} & d_{ij} \in [3, 6] \\
0 & d_{ij} \not\in [0, 6]
\end{cases} \tag{11} \]

3.5. Calculate the weight and matrix of grey evaluation

For the lowest index Uij, the evaluation coefficient of the E-th grey class is Xije. There are:

\[ x_{ije} = \sum_{k=1}^{4} f_e (d_{ijk}) \tag{12} \]

For Uij, the total evaluation coefficient of gray class is:

\[ X_{ij} = \sum_{e=1}^{4} X_{21e} \tag{13} \]

The gray evaluation weight of Uij in the e-th evaluation grey class is:

\[ r_{ije} = \frac{X_{ije}}{X_{ij}} \tag{14} \]

Comprehensive calculation results in the total evaluation vector rij of each gray class of Uij. After synthesizing the Ui grey evaluation vector, the grey evaluation matrix of Uij relative to each evaluation grey class is obtained:

\[ R_i = \begin{bmatrix} r_{i1} \\
r_{i2} \\
\vdots \\
r_{ij} \end{bmatrix} \tag{15} \]

3.6. Comprehensive evaluation

Comprehensive evaluation is:

\[ B = W \times R \tag{16} \]

At first, the middle layer Ui is comprehensively evaluated, and its evaluation result is denoted as Bi. Then the result vector of Ui is obtained as Bi. Compared with the top layer U, the gray weight matrix R=[B1,B2,…,Bi]T is formed, and the comprehensive evaluation result of U is obtained as B = W × R. According to the scoring criteria in table 2, the grey grade evaluation value vector is D=[9,7,5,3], and the comprehensive evaluation value of u is:

\[ C = B \times D^T \tag{17} \]

4. Case Analysis

Grey analytic hierarchy process (AHP) is used to evaluate the quality of a certain type of communication equipment health management according to the above index system, algorithm and evaluation model. The process is as follows:
4.1. Determination of index weight

According to the matrix $U_1$, $U_2$, $U_3$ and $U_4$, $W_1=(0.22, 0.24, 0.28, 0.26)$, $W_2=(0.20, 0.21, 0.29, 0.30)$, $W_3=(0.23, 0.22, 0.27, 0.28)$, $W_4=(0.21, 0.25, 0.26, 0.28)$

4.2. Evaluation sample matrix

Organize four experts to score each index of health management quality evaluation of a certain type of communication equipment, and the evaluation results are shown in Table 3 below.

| Experts 1 | Experts 2 | Experts 3 | Experts 4 |
|-----------|-----------|-----------|-----------|
| U_1_1     | 8         | 7         | 9         | 6         |
| U_1_2     | 9         | 8         | 8         | 7         |
| U_1_3     | 7         | 8         | 7         | 9         |
| U_1_4     | 6         | 9         | 8         | 7         |
| U_2_1     | 7         | 7         | 6         | 8         |
| U_2_2     | 8         | 7         | 6         | 8         |
| U_2_3     | 9         | 8         | 7         | 7         |
| U_2_4     | 7         | 6         | 7         | 8         |
| U_3_1     | 6         | 8         | 5         | 7         |
| U_3_2     | 7         | 9         | 8         | 7         |
| U_3_3     | 7         | 6         | 7         | 8         |
| U_3_4     | 7         | 9         | 8         | 7         |
| U_4_1     | 8         | 9         | 8         | 8         |
| U_4_2     | 9         | 8         | 8         | 7         |
| U_4_3     | 7         | 6         | 7         | 7         |
| U_4_4     | 9         | 8         | 9         | 8         |

The evaluation sample matrix of $U_1$, $U_2$, $U_3$ and $U_4$ can be calculated from table 3 as follows:

$$D_1 = \begin{bmatrix} 8 & 7 & 9 & 6 \\ 9 & 8 & 8 & 7 \\ 7 & 8 & 7 & 9 \\ 6 & 9 & 8 & 7 \end{bmatrix}, \quad D_2 = \begin{bmatrix} 7 & 7 & 6 & 8 \\ 8 & 7 & 6 & 8 \\ 9 & 8 & 7 & 7 \\ 7 & 6 & 7 & 8 \end{bmatrix}, \quad D_3 = \begin{bmatrix} 6 & 8 & 5 & 7 \\ 7 & 9 & 8 & 7 \\ 7 & 6 & 7 & 8 \\ 7 & 9 & 8 & 7 \end{bmatrix}, \quad D_4 = \begin{bmatrix} 8 & 9 & 8 & 8 \\ 9 & 8 & 8 & 7 \\ 7 & 6 & 6 & 7 \\ 9 & 8 & 9 & 8 \end{bmatrix}$$

4.3. Comprehensive evaluation results and analysis

The evaluation result of the intermediate layer index $U_i$ which can be calculated by the formulas (8)~(16) is as follows:

$$B_1=(0.31, 0.31, 0.29, 0.27) \quad B_2=(0.32, 0.31, 0.28, 0.26)$$
The evaluation vector \( d \) of evaluation sample is \([9, 7, 5, 3]\), the evaluation target gray evaluation matrix \( r \) is \([B_1, B_2, B_i]\), and the output \( b \) of formula (16) is \( w r = (0.32, 0.31, 0.28, 0) \), from which a complex communication system can be obtained:

\[
C = B \times D^T = (0.32, 0.31, 0.28, 0) \times (9, 7, 5, 3) = 7.54
\]  

According to the scoring standard, it can be judged that the evaluation result of the health management quality of the communication equipment is good, and the evaluation result accords with the actual result.

5. Conclusion

Based on the grey analytic hierarchy process, this paper evaluates the health management quality of complex communication systems, and reasonably constructs the health management quality evaluation index system. The analytic hierarchy process is used to determine the index weight, and the gray theory is used to analyze the gray level of each index, and the weight vectors of different gray classes are constructed. The gray evaluation coefficient and total gray coefficient of each index are calculated, and finally the evaluation value is obtained. This method fully adopts the combination of quantitative calculation and qualitative analysis, which reduces the influence of subjective factors. The example proves that the method is scientific and effective, and improves the scientificity and effectiveness of health management quality assessment.

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