Qualitative Evaluation Technology of Complex Equipment Guarantee Resources Based on Grey Theory

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Abstract. With the development of technology, equipment is more and more complicated. How to qualitatively evaluate the quality and integrity of an equipment guarantee resources is a complex process. In order to solve the complexity problem and improve the evaluation effect, the equipment guarantee resources are decomposed into guarantee spare parts, guarantee equipment, support facilities, technical materials, training and training guarantee, computer resources, packaging, loading and unloading, storage and transportation, and security personnel resources in eight aspects. At the same time, a qualitative evaluation technique for complex equipment guarantee resources based on grey theory is proposed. In addition to the general evaluation of scores through scores, the gray correlation calculation is used to calculate the overall evaluation of the resources. The degree of relevance allows the relevant personnel to have a detailed understanding of the overall situation of the guarantee resources and the importance of each part.

1. Preface
With the continuous development of technology, equipment guarantee resources have become more and more complex, and maintenance personnel must spend a lot of energy to manage a large number of various types of equipment guarantee resources without any specificity. Evaluation experts can only perform a simple scoring assessment on each resource. There is a lack of a link between the maintenance personnel and the evaluation expert. Maintenance personnel cannot clearly know which part or parts of a certain protection resource the evaluation expert is material, so it can only take a lot of time to maintain all aspects of the resources. Nowadays, a new evaluation technology is needed, which can contact the maintenance personnel and evaluation experts, saving time and improving maintenance efficiency.

This paper proposes a qualitative evaluation technique for complex equipment guarantee resources based on grey theory. The equipment guarantee resources are divided into safeguard rooftops, support equipment, support facilities, technical materials, training and training support, computer resources, packaging, loading and unloading, storage and transportation, and security personnel resources. In addition to the scoring assessment, a score evaluation is also required for each of the eight aspects. The evaluation technique calculates the relevance of the eight aspects to the overall score. In this way, maintenance personnel can know where the maintenance of the equipment guarantee resources is focused and can be more targeted maintenance.
This paper consists of four parts. The first chapter introduces the relevant knowledge of grey theory, the second chapter proposes the decomposition and modeling of guarantee resources, the third chapter proposes gray estimation method, and the fourth chapter gives the specific implementation steps.

2. Grey system theory
A system is constantly changing due to many interior factors. And there are certain rules and interconnections between these factors. In order to find out the internal rules of the system, some inferences are made based on changes outside the system. Thereupon, the systems include white system, grey system and black system.

For the lack of data, poor information, and uncertain grey system, Deng Julong scholar published a paper "Grey System Control Problem" in 1982, proclaiming the birth of the grey system theory [1]. Since 1982, the monographs of grey system (social economy), the grey control system, and grey planning have been published.

After more than 30 years of development, the grey system theory has established a structural system of emerging disciplines [2]. The main contents include the theoretical system based on grey set, the analysis system based on grey relational space, the method system based on grey sequence generation, the model system based on grey model (GM), and the main technical system based on system analysis, assessment, modeling, forecasting, decision making, control, and optimization. Grey set, grey algebra system, grey equation, grey matrix, etc. are the basis of grey system theory [3]. In addition to the grey correlation analysis applied in this paper, the grey analysis also includes grey clustering and grey statistical evaluation [4].

In order to deal with the problem of less data and poor information, the grey system theory puts forward the concept of relevance, which reflects the characteristics and degree of dynamic correlation of various factors within the system [5]. At present, many models have been developed for the grey relational analysis model. The most widely used and most widely used is the Deng's model [6]. In addition, there is a new method for calculating the correlation degree of grey-scale correlation entropy [7], a weighted grey correlation degree [8] constructed by weighting the correlation coefficient of each point.

To model the grey system, the first step is to analyze the rules based on system changes and to express them as much as possible in mathematical language. The method adopted is generally a discrete model, which is analyzed step by piece in units of time segments. However, the shortcomings of the discrete model are also obvious, that is, the predictive ability is weak [9]. Even though discrete approximation models of continuous systems are still useful in many engineering applications, in some specific fields of research, it is often desirable to use differential equation models because they are closer to the essence of the system.

A new understanding of the objective system is the basis of the grey system theory. Although some systems have less information, because it is a shaped system, functionality and order are inevitable, but the laws are not exposed. A major feature of the grey system is that everything is seen as "inevitable." In the analysis of the grey system, these random quantities that we used to think are considered to be in accordance with certain specific laws. These grey quantities can exhibit a regular sequence or function as long as a certain treatment is used. This process of gradually analyzing the grey system is called whitening [10].

This evaluation technique will evaluate the overall score of the equipment guarantee resources and the scoring of all aspects as a gray system. As long as we can find the relevance of each aspect to the overall score, we can directly reflect the importance of the each aspect according to its value.

3. Guarantee resource decomposition and modeling
The wide varieties of guarantee resources include spare parts, technical documents, human resources and training. How to determine the evaluation requirements is very difficult. A solution is that: the guarantee resources are divided into guarantee spare parts, guarantee equipment, guarantee facilities, technical materials, training and training guarantee, computer resources, packaging, loading and unloading, storage
and transportation, and guarantee personnel [10]. Combining specific equipment test requirements, a specific evaluation requirement is proposed for eight aspects of guarantee resources.

Figure 1. Decomposition of guarantee resources

4. Guarantee resource grey scale estimation method

The evaluation of complex equipment guarantee resources involves many aspects, and the evaluation experts are limited. The above characteristics indicate that the evaluation process has the characteristics of “small sample, poor information” for uncertainty system. Therefore, grey-scale estimation method based on grey theory is proposed to evaluation guarantee resource.

Because it is an evaluation of guarantee resources for complex equipment, there are bound to be multiple aspects in the evaluation process, experts need to score each aspect separately. The grey scale estimation method based on the grey theory can not only score the various aspects in general, but also give the importance of each aspect according to the overall impression score, which is calculated by experts based on the judgment of their own experience and knowledge.

The theoretical processing steps are given below:

Step 1. Record the scores of each expert. The scoring items include the overall impression score stored in an array \( a_0(t) \) and the scores of the individual evaluation criteria are stored in an array \( a_i(t) \).

Step 2. The formula \( \xi(k) = \frac{\min \cdot \min |a_0(t) - a_i(t)| + \rho \cdot \max \cdot \max |a_0(t) - a_i(t)|}{|a_0(t) - a_i(t)| + \rho \cdot \max \cdot \max |a_0(t) - a_i(t)|} \) is the definition of the correlation coefficient of the Deng's model in the grey system theory. In the formula, \( \rho \) is called the resolution coefficient. Generally speaking, \( \rho = 0.5 \) is scattered enough to allow us to observe the correlation coefficient.

Step 3. The formula \( r = \frac{1}{t} \sum_{i=1}^{t} \xi(k) \) is used to obtain the degree of relevance.

A brief flow chart is given below:
5. Specific implementation
Assume that there is now a certain guarantee resource waiting for evaluation. The evaluation is divided into eight areas, namely, spare parts evaluation, equipment evaluation, facility evaluation, technical materials evaluation, training evaluation, computer resource evaluation, packaging and transportation evaluation, and guarantee personnel evaluation. The scores are given by the two experts, which are shown in table 1 and table 2.
Table 1. The scores of guarantee resources by expert 1

| Eight areas                      | score |
|----------------------------------|-------|
| spare parts                      | 61    |
| equipment                        | 65    |
| facility                         | 90    |
| technical materials              | 66    |
| training                         | 70    |
| computer resource                | 98    |
| packaging and transportation      | 60    |
| guarantee personnel              | 70    |
| overall impression score         | 92    |

Table 2. The scores of guarantee resources by expert 2

| Eight areas                      | score |
|----------------------------------|-------|
| spare parts                      | 65    |
| equipment                        | 62    |
| facility                         | 93    |
| technical materials              | 61    |
| training                         | 68    |
| computer resource                | 96    |
| packaging and transportation      | 62    |
| guarantee personnel              | 71    |
| overall impression score         | 91    |

The degree of relevance is determined according to the method described above, in which, \( \min \cdot \min |a_{it} - \alpha_{it}| = 2, \max \cdot \max |a_{it} - \alpha_{it}| = 32 \), then the final correlation result is shown in table 3:

Table 3. The degree of relevance calculation results

| Eight areas                      | Relevance degree |
|----------------------------------|------------------|
| spare parts                      | 0.406            |
| equipment                        | 0.410            |
| facility                         | 1.000            |
| technical materials              | 0.410            |
| training                         | 0.468            |
| computer resource                | 0.838            |
| packaging and transportation      | 0.407            |
| guarantee personnel              | 0.487            |

The degree of relevance directly reflects its importance. From the calculation results, it can be seen that the largest correlation is the facility, with the size of 1.000, followed by the computer resource, which is 0.838. It indicates that for the equipment guarantee resources in the above example, the evaluation experts believe that facilities and computer resources are the most important and need to be focused on management and maintenance. The other guarantee resources have little difference in relevance, and the values of relevance are not large, so they are a less important equipment guarantee resource.

6. Conclusion
At present, due to the diverse resources of complex equipment, it is difficult to generalize which aspect is important and which aspect is not important [12]. For equipment guarantee resources, it can only be
valued in all aspects, but it is difficult to determine the key points. Based on the grey theory, the complex equipment guarantee resource assessment method can not only obtain the general scoring assessment, but also obtain the importance of all aspects of guarantee resources. For example, for a part that is often worn and needs to be replaced frequently, the spare parts guarantee resources will be far more important than other guarantee resources, and if this happens to be a fragile part, the importance of transportation will increase. It is difficult to draw out the importance during such aspects using the general assessment method. But the proposed method in this paper can find the relevance of various aspects of the overall evaluation, so that the guarantee personnel can grasp the key points and do more with less.

At the same time, the core idea of this evaluation technology is to use the relevant knowledge of grey theory to calculate the degree of relevance of each small aspect to the overall. With the development of technology, equipment guarantee resources may no longer be limited to the eight aspects. Faced with this situation, the qualitative evaluation technology of complex equipment guarantee resources based on the grey theory has very good adaptability, and can be changed by changing the number of comparison series into the corresponding small number, which has good scalability.

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