Design and application of support capability evaluation system for complex system

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Abstract. Aiming at the problem of low accuracy and effectiveness of complex system support capability assessment, an index system was constructed on the basis of studying the characteristics of support capability generation elements, in which the systematicness, comprehensiveness and the importance of key links of complex system support were considered, a complex system supportability evaluation model was proposed based on weight scores and key levels, and the score and level of the complex system supportability evaluation were obtained through comprehensive evaluation. A corresponding evaluation system was designed which provided the means and support for the informatization of support capability evaluation of complex systems.

1. Introduction

Complex system support capability refers to the capabilities of organization and command, use and management, technical support, supply and deployment support, etc., which are necessary to ensure the equipment successfully finish various tasks and improve its support efficiency. It is actually an organic collection of multiple capabilities, each judgment of capability itself has vague uncertainty[1,2]. The evaluation of the support capability of complex systems can be divided into the evaluation for the support system and the evaluation for the task. The assessment of the support capability for the support system is a static assessment. It does not aim at specific task process, but evaluates the support system according to the type, quantity of the support resources, personal quality and experience[3,4]. This article is about the static assessment of the support capability of the support system.

There are many methods for evaluating support capabilities, mainly including multivariate statistical theory, uncertainty theory, multi-attribute methods, data mining methods, interdisciplinary methods, and combined model evaluation method[5,6]. In order to consider the systematicness and comprehensiveness of equipment support as a whole and highlight the importance of key links and projects, this paper uses a dual model to comprehensively evaluate the supportability of complex systems. One is a weighted score evaluation model that considers the impact of the entire system, and the other is a key grade evaluation model that focuses on the impact of key links.
2. Weight score evaluation model

2.1. Construction of judgment matrix
According to the established evaluation index system of complex system support capability, a nine-scale method is used to conduct a questionnaire survey on the weights of indicators at all levels\[7\]. The questionnaire survey should cover military and political chiefs, agency business leaders, grassroots leaders, technical backbones, academic experts, etc. Taking the first-level indicators as an example, after a preliminary questionnaire survey, the first-level indicator weight judgment matrix is shown in Table 1.

Table 1. the first-level indicator weight judgment matrix

| the first-level indicator | A    | B    | C    | D    | E    |
|--------------------------|------|------|------|------|------|
| A                        | 1    | 2.40 | 2.80 | 5.50 | 3.20 |
| B                        | 1/2.40 | 1    | 1.20 | 2.30 | 1.30 |
| C                        | 1/2.80 | 1/1.20 | 1    | 2.00 | 1.15 |
| D                        | 1/5.50 | 1/2.30 | 1/2.00 | 1    | 0.58 |
| E                        | 1/3.20 | 1/1.30 | 1/1.15 | 1/0.58 | 1    |

In which: A is human resources, B is equipment, C is technical sites, D is information resources, and E is management.

2.2. Solve the judgment matrix and check its consistency
Using the analytic hierarchy process, after preliminary analysis, the maximum eigenvalue of the judgment matrix is $\lambda_{max}=5.0003$, the corresponding eigenvector is $(0.835, 0.349, 0.298, 0.151, 0.262)$, and the Consistency index is C.I. = 0.000075. It can be seen from Table 1 that the average random consistency index R.I. = 1.12 of the fifth-order judgment matrix. Therefore, the consistency ratio C.R. = 0.000067 << 0.10, the consistency of the judgment matrix analysis results is good. Therefore, the weights of the first-level indicators are: 0.441, 0.184, 0.157, 0.080, and 0.138. For the second-level indicators and third-level indicators under each first-level indicator, the above analytic hierarchy process is used to obtain the weight of the corresponding indicator, as shown in Table 2.

Table 2. weights of the second-level and third-level indicators

| The First-level indicators | The corresponding weight of the secondary indicator |
|---------------------------|---------------------------------------------------|
| Human resources           | 0.637, 0.114, 0.067, 0.182                        |
| Equipment                 | 0.331, 0.447, 0.111, 0.111                        |
| Technical sites           | 0.5, 0.5                                           |
| Information resources     | 0.622, 0.378                                       |
| Management                | 0.373, 0.176, 0.176, 0.135, 0.070, 0.070          |

| The second-level indicators | The corresponding weight of the third indicator |
|----------------------------|-----------------------------------------------|
| personnel quality          | 0.185, 0.320, 0.495                           |
| Combat readiness           | 0.4, 0.6                                      |
| Training                   | 0.4, 0.6                                      |
| Equipment management       | 0.4, 0.6                                      |
| Safety management          | 0.4, 0.6                                      |
| Logistics                  | 0.4, 0.6                                      |

2.3. Index score
For easy evaluation, and refer to the current evaluation method of complex system support capability,
the weight of the first-level indicators were expressed in a thousand-point system. The weights of the first-level indicators after rounding are: 440 points for human resources support, 180 points for equipment support, 160 points for technical sites support, 80 points for information resources, and 140 points for management.

2.4. Index score evaluation

In the actual evaluation process, the evaluation scores of the underlying indicators can first use a percentage system to obtain a score $S_{\text{percentage}}$, then obtain the actual score $S_{\text{actual}}$ through the following equation with weight score $S_{\text{weight}}$.

$$S_{\text{actual}} = S_{\text{weight}} \times S_{\text{percentage}} / 100$$

However, the score of the personnel quality level A1 indicator is relatively special. Because the personnel quality level should be evaluated on the basis of the individual quality level, the weight scores of the three three-level indicators under it are evaluated in the form of weight ratio in the actual evaluation process. Personal quality level assessment is to evaluate the basic literacy A11, theoretical knowledge level A12 and practical operation skill level A13 of the personnel in the army, and the scores of the three indicators are integrated to obtain each person's personal quality level. Then get the overall personal quality level of the army, and finally get the score of the personnel quality level A1 indicator. The calculation process is as follows:

1. The individual's basic quality A11, theoretical knowledge level A12 and practical skills level A13 are evaluated on a 100-point scale to get $S_{\text{personalA11}}$, $S_{\text{personalA12}}$ and $S_{\text{personalA13}}$.

2. Transforming the $S_{\text{personalA11}}$, $S_{\text{personalA12}}$ and $S_{\text{personalA13}}$ to evaluation level $L_{\text{personalA11}}$, $L_{\text{personalA12}}$, $L_{\text{personalA13}}$ refer to four grades: excellent (above 90 points), good (75-90 points), passing (60-75 points), and failing (below 60 points).

3. Obtain personal quality level $L_{\text{personalA1}}$ by taking the minimum of $L_{\text{personalA11}}$, $L_{\text{personalA12}}$ and $L_{\text{personalA13}}$.

4. On the basis of personal quality level $L_{\text{personalA1}}$, The personal qualities levels of personnel in the army are assigned based on the criteria of excellent (100 points), good (80 points), passing (60 points), and failing (40 points), and the arithmetic average is taken to get $S_{\text{personalA1}}$.

5. Transform the average personal quality level points into average personnel quality points $S_{A1}$ by following formula.

$$S_{A1} = S_{\text{weightA1}} \times S_{\text{personalA1}} / 100$$

6. Weight score evaluation model and its evaluation result

The evaluation model for the weighted score of the support capability of complex systems is:

$$S = \sum_{i=A}^{E} \sum_{j=1}^{n} S_{ij}$$

In which: $S$ is the evaluation weight score of complex system support capability; $S_{ij}$ is the evaluation weight score of each second-level evaluation indicator; $n$ is the number of second-level indicators included in each first-level indicator.

The preliminary definition of the rating criteria for the weighting value of the evaluation capability of complex systems is as follows:

- Excellent: 900 points and more;
- Good: 750 points and more;
- pass: 600 points and more;
- failed: less than 600 points;

Refer to above standard, the corresponding weight grade value $R_{\text{weight}}$ can be get according to the weight score.

Therefore, the weight score evaluation model can be used to obtain the weight score and weight level ($S$ and $R_{\text{weight}}$) of the complex system support capability evaluation.
3. Key level assessment model

In order to highlight the important roles of key links and projects in the process of equipment support, and to improve the shortcomings of the weighted score evaluation model, a key level evaluation model was set up in the evaluation of the complex system support capability. The indexes that play a key role in equipment support are preliminary sorted out by analyzing the established complex system support capability evaluation index system as follows:

1. Job certificate satisfaction rate R1
2. Support equipment satisfaction rate R2
3. Facilities satisfaction rate R3
4. Technical data support level R4
5. Combat readiness support level R5

Four levels of excellent, good, pass and fail are used to formulate the index rating criteria. For the above five key indicators, the corresponding grade value can be get according to the corresponding evaluation criteria. This subject uses the algorithm of minimum value to evaluate the key index level of the complex system support capability according to the wooden barrel principle.

The evaluation model of key indicators of complex system support capability is as follows:

$$R_{key} = \min (R1, R2, \ldots, R_i)$$

In which: $R_{key}$ is the key indicator level of complex system support capability; $i$ is the number of key indicators.

4. Evaluation model of supportability of complex system based on weight score and key level

In summary, the evaluation model of the supportability of complex systems is a dual-model structure, and the evaluation process of the supportability of complex systems is as follows:

The first is to obtain the weight of each evaluation index using the analytic hierarchy process based on the established evaluation index system of complex system support capability, and then obtain the weight score and weight grade ($S$, $R_{weight}$) according to the weight score evaluation model.

The second is to set the key indicators of the complex system's supportability according to the actual situation, and use the key indicator evaluation model to obtain the key indicator levels $R_{key}$.

The third is to get the final rating $R$ of the complex system support capability assessment by taking the smaller one of $R_{weight}$ and $R_{key}$.

Using the evaluation model of complex system support capability, the score and level ($S$, $R$) of complex system support capability evaluation are finally obtained. The score $S$ mainly reflects the perfection level that the military support equipment can achieve, and the level $R$ mainly reflects the capability level that the military support equipment can reach.

5. Design and application of system

5.1. Overall system design

This system was developed using Qt software in the VS2010 development environment. Qt is a cross-platform C++ graphical user interface application framework. Qt has excellent cross-platform features. Using the software developed by it, the same code can be compiled and run on any supported platform without modifying the source code. It will automatically express the unique graphics style of the platform. Qt is completely object-oriented, easy to extend, and has a very high degree of modularity and good reusability, and also has a rich application programming interface (API). Qt is widely used in application development of various system platforms[8, 9]. The basic framework of the system is shown in Figure 1.
5.2. System function.
The system mainly includes four modules: standard establishment, expert scoring, rating and data storage.

5.2.1. Standard establishment
(1) Set total score. Set total score for the evaluation of the support capability of complex systems through the "Scoring Criteria Entry" option.

(2) Judgment matrix entry. Input the questionnaire survey results of the index weights at all levels through the "Scoring Criteria Entry" option. After the entry of the judgment matrix for each expert is completed, click "Add".

(3) Standard score calculation. After the judgment matrix data is recorded, click "Standard Score Calculation", the software will automatically settle the judgment matrix and check its consistency, and obtains the weight score of each level of indicators, which is standard score.

(4) View the set standard score. After the judgment matrix of all indicators is input and calculated, you can get the standard score of the established complex system supportability by "Viewing the Set Standard Score" in the "Scoring Standard Entry" option.

5.2.2. Supportability
After the evaluation criteria are established, the bottom indicators at all levels are scored. In the evaluation of personnel quality levels, the affiliation personnel are scored one by one, and the evaluation grade of individual personnel quality level can be obtained; after the evaluation of the individual personnel quality levels of affiliated personnel, the overall personnel quality level score can be calculated; During the process, all or several of the items can be scored at one time.

5.2.3. Rating
After scoring all the assessment items, a rating of the complex system's support capability is made.

(1) Set assessment rules
Before proceeding with rating assessment, it is necessary to set assessment rules. The software can set different evaluation rules for different items such as total score, key level indicators, and personnel quality levels.

(2) Score evaluation
After setting the evaluation rules for the total score, key indicators, personnel quality level and other items, the evaluation results of the complex system's supportability can be calculated, which is the total score and the grade.
5.2.4. Data storage
After the evaluation of the support capability of a complex system is completed, data such as index weight, standard scores at various levels, index scores at various levels, evaluation rules and evaluation results can be exported. If the data are needed, it can also be viewed by importing into the software.

6. Conclusion
In this paper, the weight score evaluation model was established firstly, where the construction of judgment matrix and index score was researched for the index score evaluation. Secondly, key level assessment model was established. Then the evaluation model of supportability of complex system based on weight score and key level was researched. Finally, a corresponding evaluation system was designed which provides the means and support for the information of support capability evaluation of complex systems.

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