A Method For Selecting Command Nodes Oriented To Succession Command Scenarios

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Abstract. Succession command is a command method to change command in the face of uncertain factors or irresistible damage. Alternative command nodes need to complete command transfer to achieve uninterrupted command. Facing the alternative scenarios of multiple command nodes, this article proposes a method for selecting the replacement command nodes, researches the command and control capability requirements, analyzes the command capability of the command organization, extracts the key performance indicators of the command and control system to construct an evaluation index system, and uses the analytic hierarchy process to determine the index rights. Based on the value, a hybrid TOPSIS method and grey relational analysis evaluation model is proposed to evaluate and sort the candidate command nodes. Experiments are carried out through the simulation data of the command system. The experimental results prove that the method can effectively select the replacement command nodes and provide preparation for the subsequent replacement command.

Keywords: succession command; evaluation index; analytic hierarchy process; grey correlation; TOPSIS.

1. Introduction

In mechanized warfare, the commander uses a centralized command method to formulate a thorough plan to control the autonomous actions of the subordinates to a minimum, in order to minimize the uncertainty in the combat process. However, the actual command process is full of uncertainty. During the information warfare period, it should be action-oriented, mission-centric, and network-based, effectively collecting information from various combat platforms, changing the command mode according to the changes in the battlefield environment, and flexibly controlling the superiors and subordinates, through the direct command of the superior terminal or adaptive command mode that the lower level takes over the upper-level command authority to complete combat tasks[1-3].

However, a fully flexible adaptive command method is still difficult to achieve today. The combat command is still human-led and dependent on the commander’s decision-making. At the same time, in order to adapt to new combat conditions and combat missions, and maintain the continuity and effectiveness of combat command capabilities, the command and control system also needs to have the ability to take over the command. The selection of a successor node suitable for a continued command among the candidate command nodes is of key significance for subsequent realization of succession command. In the past command process, the factors considered by decision-makers are...
usually incomplete and lack objectivity. At the same time, they are not considered comprehensively with the actual performance of the command system. The selection of the successor command node that comprehensively considers multiple factors is actually a multi-attribute decision-making problem. Some people use the multi-attribute decision-making method of AHP fuzzy comprehensive evaluation to make choice, combines gray theory with AHP method to evaluate the index system related to combat effectiveness, make selection of railway system projects by AHP and best worst method [2].

This paper decides to use the subjective weighting analytic hierarchy process to assign weights to the indicators, which can fully reflect the will of decision-makers, and at the same time combine the gray relational analysis method and TOPSIS evaluation method for a comprehensive evaluation, so as to make a more comprehensive and objective evaluation. Alternative command nodes, finally select the ideal command node, and verify the feasibility of the method through the command system simulation data.

2. Construct an evaluation index system for succession command

The evaluation of alternate command nodes should first determine the evaluation indicators. For combat command, multiple factors should be considered comprehensively. The evaluation of each command node is equivalent to the comprehensive evaluation of the command system and the command organization of the node. This paper constructs an evaluation index system for the replacement command scenario, selects representative key indicators for comprehensive evaluation from two aspects of command capability and command system performance, to ensure that the evaluation is simple and efficient, and has auxiliary significance for the commander's decision-making. The constructed indicator system is shown in Figure 1.

![Fig. 1 Comprehensive evaluation index system for the selection of replacement nodes](image)

The ability of commanders[3] is comprehensively evaluated through three indicators, professional technical level, actual installation and operation ability, professional training. The ability of command posts is evaluated through two indicators, command experience and mission experience.

Weapon control capability is measured by calculating the correct rate of monitoring information, as shown in formula (1).

$$M_{ac} = \frac{\text{collect}_{info} \#}{\text{Actual}_{info}}$$

$collect_{info}$ refers to the information collected by weapon monitoring, $Actual_{info}$ refers to the actual weapon status information.

Effective control capability is evaluated by comparing the consistency of the commands issued by the system with the execution commands of the weapon, as shown in formula (2).
The comprehensive performance of the system is to consider the reliability and survivability[4] of the control system by analyzing the actual performance indicators of the system. System reliability is a measure of whether a system can work normally and stably, and transmit information correctly and effectively. System reliability is considered through three aspects: system stability, data transmission delay, and channel connectivity. System survivability evaluation is the evaluation of the system’s survivability in the execution of combat missions, mainly through two aspects of data link survivability and node survivability.

3. Grey relational TOPSIS alternative command node decision model

Step 1. Determine the decision matrix
Suppose there are m evaluation objects and n evaluation indicators. Each evaluation object index value constitutes a decision matrix \( M = (x_{ij})_{m \times n} \), \( x_{ij} \) is the evaluation index value.

Step 2. Standardized processing of evaluation index values
The index normalization method selects the vector normalization method. For the benefit-type index, the processing method is shown in formula (3).

\[
y_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m}x_{ij}^2}}
\]

For cost indicators, the processing method is as shown in formula (4).

\[
y_{ij} = \frac{1/x_{ij}}{\sqrt{\sum_{j=1}^{m}(1/x_{ij})^2}}
\]

Step 3. Determine the index weight and calculate the weighted decision matrix
The weight of the index determines the degree of influence of the index on the evaluation result. Since the replacement of command needs to consider the decision of the commander, it is more suitable to adopt the analytic hierarchy process to determine the index weight. The analytic hierarchy process is to decompose and combine a complex problem to form a top-down hierarchical structure, construct a judgment matrix through the pairwise comparison results between related indicators, and use the judgment results to comprehensively calculate the weights between the indicators.

Step 4. Determine the distance to the positive and negative ideal plan[5]
The positive ideal plan \( C^+ \) is usually the optimal value composition of each alternative plan index in the weighted normalized matrix, and the negative ideal plan \( C^- \) is usually the worst value composition of the index value of each alternative plan.

The \( j \)th index value of the positive ideal scheme \( C^+ \) is shown in formula (5)

\[
C^+_j = \begin{cases}
\max_{y_{ij}} & \text{is the benefit index} \\
\min_{y_{ij}} & \text{is the cost index}
\end{cases} \quad j = 1, 2, \ldots, n
\]

The \( j \)th index value of the negative ideal scheme \( C^- \) is shown in formula (5)

\[
C^-_j = \begin{cases}
\min_{y_{ij}} & \text{is the benefit index} \\
\max_{y_{ij}} & \text{is the cost index}
\end{cases} \quad j = 1, 2, \ldots, n
\]

The distance between the alternative plan and the positive ideal plan is shown in formula (7).

\[
d^+_j = \sqrt{\sum_{i=1}^{n}(y_{ij} - C^+_j)^2}, \quad j = 1, 2, \ldots, m
\]

The distance between the alternative plan and the negative ideal plan is shown in formula (8).
\[ d_j = \sqrt{\sum_{i=1}^{n} (y_{ij} - c_j)^2}, \quad j = 1, 2, \ldots, m \]  

**Step 5.** Determine the relevance of alternatives

Calculate the gray correlation coefficient. \( \xi_{ij} \) represents the correlation coefficient of the alternative scheme \( x_i \) on the \( j \)th index, \( \rho \) is the resolution coefficient, \( 0 < \rho < 1 \). If \( \rho \) is smaller, the difference between correlation coefficients is larger, and the distinguishing ability is stronger. The correlation coefficients between the alternatives and the positive and negative ideals are shown in formula (9) and (10).

\[
\begin{align*}
\xi_{ij}^+ &= \frac{\min_{j=1}^{m} \left[ \min_{i=1}^{n} \left[ c_j^+ - y_{ij} \right] + \rho \max_{i=1}^{n} \left[ c_j^+ - y_{ij} \right] \right]}{\max_{i=1}^{n} \left[ c_j^+ - y_{ij} \right] + \rho \min_{i=1}^{n} \left[ c_j^+ - y_{ij} \right]} \\
\xi_{ij}^- &= \frac{\min_{j=1}^{m} \left[ \min_{i=1}^{n} \left[ c_j^- - y_{ij} \right] + \rho \max_{i=1}^{n} \left[ c_j^- - y_{ij} \right] \right]}{\max_{i=1}^{n} \left[ c_j^- - y_{ij} \right] + \rho \min_{i=1}^{n} \left[ c_j^- - y_{ij} \right]} 
\end{align*}
\]

Calculating the gray correlation degree of the alternatives according to the gray correlation coefficient is shown in equation (11) and equation (12) respectively.

\[
\begin{align*}
R_i^+ &= \frac{1}{n} \sum_{j=1}^{n} \xi_{ij}^+ \\
R_i^- &= \frac{1}{n} \sum_{j=1}^{n} \xi_{ij}^- 
\end{align*}
\]

**Step 6.** Calculation of Mixed Relative proximity

The TOPSIS method calculates the relative closeness of the Euclidean distance to obtain the closeness of the alternatives to the positive ideal solution. The proximity calculation is shown in formula (13).

\[ S_i = \frac{d_i^-}{d_i^- + d_i^+} \]

Grey relational analysis can obtain the similarity between the alternatives and the positive ideal scheme by calculating the relative closeness of the relevance degree. The relative closeness is calculated by the formula (14).

\[ G_i = \frac{R_i^-}{R_i^- + R_i^+} \]

A comprehensive evaluation of the relative closeness of the mixture is shown in formula (15)

\[ T_i = \alpha S_i + \beta G_i \]

Among them, \( \alpha \) and \( \beta \) are weight coefficients, which can be determined according to the preference of the decision-maker for distance and similarity, \( \alpha + \beta = 1 \).

The model data can obtain the ranking result of the alternatives by calculating and sorting the relative closeness of the mixture, and the optimal solution is the one with the largest relative closeness of the mixture.

4. **Experimental analysis**

According to the three-level indicators of the evaluation index system, the simulation data of a certain command system deployed in different environments is selected, constructed the decision matrix.

Through the analytic hierarchy process, the importance of the indicators in the indicator system is compared in pairs. Construct a judgment matrix through expert evaluation results, calculate the maximum eigenvalue of the matrix, and its corresponding eigenvector is the weight vector of the indicator.
Table 1 shows the corresponding index results according to the steps of the analytic hierarchy process.

| Index | A2 | A1 | A11 | A12 | A13 | A21 | A22 | A111 | A112 |
|-------|----|----|-----|-----|-----|-----|-----|------|------|
| Weight| 0.4| 0.6| 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.04 | 0.04 |

| Index | A113 | A121 | A122 | A131 | A132 | A211 | A212 | A213 | A221 |
|-------|------|------|------|------|------|------|------|------|------|
| Weight| 0.02 | 0.05 | 0.05 | 0.1  | 0.1  | 0.15 | 0.075| 0.075| 0.15 |

| Index | A222 |
|-------|------|
| Weight| 0.15 |

Tab 1. Index weights corresponding to the index system

Except for system stability A211 and data transmission delay A212, which are cost-based indicators, the rest are benefit-based indicators. After normalization, the weighted normalization matrix can be obtained by weighting calculation, and the positive and negative ideal solutions are determined at the same time.

Calculate the distance between the candidate command post and the ideal plan according to equations (7) and (8)

\[ d^+_i = (0.1139 \ 0.1028 \ 0.0883 \ 0.0973 \ 0.0441 \ 0.1465) \]
\[ d^-_i = (0.0617 \ 0.0795 \ 0.1140 \ 0.1258 \ 0.1438 \ 0.0465) \]

Calculate the correlation coefficient according to formula (9) and formula (10), calculate the correlation degree value according to formula (11) and formula (12).

\[ r^+_i = (0.8301 \ 0.7961 \ 0.8676 \ 0.8647 \ 0.8673 \ 0.7137) \]
\[ r^-_i = (0.7903 \ 0.8286 \ 0.777 \ 0.8022 \ 0.7872 \ 0.9539) \]

According to formula (13), the Euclidean distance correlation degree is

\[ S_i = (0.3514 \ 0.4363 \ 0.5634 \ 0.5637 \ 0.7652 \ 0.2410) \]

According to formula (14), the relative closeness of the gray correlation degree of each candidate command post is

\[ G_i = (0.5123 \ 0.4900 \ 0.5275 \ 0.5187 \ 0.5242 \ 0.4280) \]

Taking the weight coefficients \( \alpha \) and \( \beta \) as 0.5 respectively, the result of calculating the relative proximity of the mixture according to formula (15) is

\[ T_i = (0.4319 \ 0.4631 \ 0.5455 \ 0.5412 \ 0.6447 \ 0.3345) \]

The final closeness from large to small gives the final ranking result as 5>3>4>2>1>6. Comprehensive consideration of all indicators, No. 5 alternate command post is more in line with the replacement command requirements.

The comparison result of each scheme with the positive and negative ideal solution is shown in Figure 2. The system performance index has a greater influence than the command and control capability index and plays a key role in the evaluation result. Therefore, the selection of system performance index for evaluation has reference significance for the selection of command posts.
5. Conclusion
This paper constructs an evaluation index system for the succession command scenario and uses the hybrid TOPSIS method and gray correlation analysis model to combine the command data to get the final succession node. The experimental results meet the commander’s decision-making requirements and performance requirements, and it is feasible for the selection of the succession command node. Through experiments, it is found that the system performance indicators have a greater impact on the evaluation results, and at the same time, the index weights will also affect the evaluation results. Future research can consider further optimizing the weight distribution method, reducing the deviation caused by subjective factors to the results, and at the same time further improving the evaluation index system, in order to be able to make more accurate assessments and provide help for the commander’s decision-making.

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