Research on the Evaluation Model and Method of "Generaliztion, Serialization, Combination" Degree of Naval Gun

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Abstract: In China, there are some problems about the degree evaluation of "generaliztion, serialization, combination" of naval gun, such as the lack of inheritance, the incompleteness of the standard evaluation system, the limitation of the evaluation scheme, and the disunity of the evaluation standard system. In order to solve this problem, this paper established of the degree evaluation model and method of "generaliztion, serialization, combination" of naval gun, by which the coefficient of generalized number of pieces and the coefficient of generalized type spectrum. This method provides certain data support for the development and production of naval gun series.

1. Introduction
Generalization, serialization and combination are three important standardization forms of weapon equipment referred to as "three transformations "[1]. "Three transformations" has become one of the important technologies of major countries in the world to develop important and complex model systems. It is a sign that the design level of major and complex model systems is maturing Logo. All countries in the world regard "three transformations" as an important scientific and technological development strategy and an important choice of key national defense technologies [2]. The important task of naval gun "three transformations" products is to meet reasonable excess products, overcome arbitrariness, and form unified specifications and requirements.

Foreign evaluation mechanisms for naval gun weapon systems include inheritance ratio evaluation mechanism, advanced standardization, dynamic standardization, flexible standardization and economic evaluation mechanism. The evaluation of the degree of "generalization, serialization, combination" in China has not formed a unified standard system. It has weak inheritance, incomplete standard evaluation system, and limitations of evaluation schemes. It affects the development and production of new product models and causes waste of funds, so it is urgently needed. A standardized method to evaluate the degree of "three transformations" of naval guns. Naval guns are large and complex products with a wide variety of parts and complex relationships between components. The test and evaluation methods of naval gun "three chemical" are in a blank situation, and there is no suitable frame structure to evaluate the "three chemical" level of weapon naval guns. It is very different from the actual results, which affects the development and production of new models of products and causes waste of funds. Therefore, it is of great significance to study the design of the "generaliztion, serialization, combination" test and evaluation model of naval gun weapons as a key technology.
2. Evaluation Model and Method of "Three Types" Degree Evaluation

2.1 "Three" Evaluation System Framework
In the development of new models, it used the model data of existing products and borrow product information in the model spectrum to maximize inheritance and reduce low-level repetitive labor, save more resources and use other innovative technologies, so that the naval gun "three" constantly has been developed and improved.

According to the characteristics of naval gun product family, this paper starts from the naval gun three design requirements and design methods, and builds a generalized, serialized and modularized "three modernization" comprehensive evaluation framework structure. This article defines the generalized piece number coefficient and the general type spectrum coefficient, comprehensively utilizes the standardized piece number coefficient and standardized species number coefficient, and combines the expert group policy to evaluate the standardized degree scoring method to carry out the evaluation of the overall “three transformations” of the naval gun. The naval gun "generalization, serialization, combination" evaluation system framework is shown in Figure 1:

![Evaluation System Framework](image)

**Figure 1.** Framework of the evaluation system of the "three transformations" of naval guns

The generalized piece number coefficient $k_j$ is determined by the ratio of the total number of standard parts in the product $\sum b_i$, the total number of common (borrowed and unified) parts in the product $\sum t_i$ and the total number of all zero $\sum e_i + \sum b_i + \sum t_i + \sum w_i$, department and group (whole) parts. It calculated as follows:

$$k_j = \frac{\sum b_i + \sum t_i}{\sum e_i + \sum b_i + \sum t_i + \sum w_i} \quad (1)$$
In this paper, the ratio of the types of general components in the model spectrum to the types of all spectrum components is defined as the general spectrum selection coefficient \( kp \).

\[
kp = \sum_{i=1}^{n} \sum_{j=1}^{m} e_{pj} / \sum_{j=1}^{m} e_{pj}
\] (2)

2.2 Comprehensive Evaluation Model of "Three Transformations"

2.2.1. Evaluation based on AHP and expert group policy

The combination of AHP and expert group policy is used to weight the three evaluation weight vectors of the “three transformations” \([3]\), which effectively avoids the uncertainty of the objective weighting method and eases the absolute subjectivity of the subjective weighting method. First, this paper builds a set of comprehensive evaluation indicators. The first layer of indicators is the degree of “three-level” naval guns, and the second layer of indicators includes standardized piece number coefficients, generalized piece number coefficients, standardized type coefficients, and general spectrum selection coefficients.

1) The index system plan for comments is made into a table and sent to the members of the expert group. The experts are asked to rank and grade the importance of different coefficients on the degree of "three transformations". The scoring rules are as follows: experts judge the degree of influence of a coefficient on the degree of tribalization, and compare the importance of each factor according to the standard coefficients in Table 1 to score. Then, according to their relative importance, \( K_i, K_z, K_p \) are assigned corresponding values, and after comparing each other, all judgment matrices are constructed.

| Relative importance assignment | Meaning | Explanation |
|-------------------------------|---------|-------------|
| 1                             | Equally important | Indicates that the coefficient i has the same importance as the coefficient j |
| 3                             | Slightly important | Indicates that the coefficient i is slightly more important than the coefficient j |
| 5                             | Obviously important | Indicates that the coefficient i is significantly more important than the coefficient j |
| 7                             | Strongly important | Indicates that the coefficient i is strongly important compared to the coefficient j |
| 9                             | Extremely important | The coefficient i is extremely important compared to the coefficient j |

| 2,4,6, 8 | Represents the intermediate value of two adjacent degrees, used when a compromise is needed |

| Reciprocal | If the comparison between coefficient i and coefficient j is one of the above numbers, then the comparison between j and i is the reciprocal of that number. |

2) Judgment matrix The matrix is a positive reciprocal matrix:

\[
A = (a_{ij})_{n \times n}
\] (3)

3) Solve the judgment matrix to get the feature root and feature vector. The formula for calculating the consistency of expert ratings is as follows:

\[
CR = CI/RI = [(\lambda_{max} - n)(n-1)]/RI \leq 0.1
\] (4)

4) Consistency needs to be recalculated after each recovery of the comment form. After several
rounds of consultation, expert opinions tend to be consistent.

5) The combined weight of each element can be calculated, which is defined as $W = (\omega_1, \omega_2, \cdots, \omega_n)^T$. In order to obtain the relative weights of all elements in each level of the hierarchical hierarchy structure relative to the total target, the results calculated in the previous step need to be appropriately combined to calculate the relative weight of the total ranking, and the levels and results are tested at one time. It should be done layer by layer from top to bottom, and finally the lowest level element, that is, the relative weight of the priority of the decision plan and the consistency of the judgment of the entire hierarchical model.

6) Due to the different knowledge levels, performance of the experts, and different judgment preferences, there may be conflicts in the evaluation judgments made. Therefore, in the process of integrating expert opinions, it is necessary to consider the importance of different experts.

7) To evaluate a certain element, it lets n influential elements be $x_1, x_2, \cdots, x_n$, the evaluation expert set is $E_1, E_2, \cdots, E_n$. The k-th evaluation expert $E_k$ compares pairs $x_1, x_2, \cdots, x_n$ (refer to Table 2) established a judgment matrix, and the weights of the experts is $\lambda^1_B, \lambda^2_B, \cdots, \lambda^m_B$, among $\sum_{i=1}^{m} A^i_B = 1$

8) If $A = (a_{ij})_{n \times n}$ and $B = (a_{ij})_{n \times n}$ are a positive reciprocal judgment matrix, and the sum of the matrix $A$ and $B$ is $C = (c_{ij})_{n \times n}$, and the addition operation is defined as $C = A \oplus B = D$, where:

$$C = \begin{cases} a_{ij} + b_{ij} & j \geq i, i,j = 1,2,\cdots,n \\ 1/c_{ij} & j < i, i,j = 1,2,\cdots,n \end{cases}$$

(5)

9) The synthesis of expert opinions is calculated by the weighted arithmetic average or weighted geometric average method. The algorithm is defined as follows:

There are m experts, and the judgment matrix of the experts' evaluation opinions is $A^1_B$, $A^2_B$, $A^3_B$, $A^4_B$, $\cdots$, $A^m_B$; and the weight of each expert is $\lambda^1_B$, $\lambda^2_B$, $\cdots$, $\lambda^m_B$. Therefore, the comprehensive judgment matrix obtained by the weighted arithmetic average method is:

$$\overline{A} = (\overline{a}_{ij})_{n \times n} = \lambda^1_B A^1_B \oplus \lambda^2_B A^2_B \oplus \cdots \oplus \lambda^m_B A^m_B$$

(6)

The comprehensive calculation can finally converge on the basis of the probability to obtain an objective judgment matrix. It is feasible to synthesize expert opinions by this method with the increase of the number of experts.

2.2.2 Comprehensive evaluation model

In this paper, comprehensive evaluation model of the “three transformations” of naval guns is constructed which based on the expert group policy scoring method, combined with the evaluation model and weighted separately. The comprehensive evaluation result is formed by the comprehensive evaluation of multiple factors. Each evaluation factor is not treated equally, but its weight coefficient is determined according to the degree of importance of each factor. The model is as follows:

$$B = \overline{A} \cdot \overline{W} = [K_r, K_f, K, (\omega_1, \omega_2, \omega_3, \omega_4)] \cdot (\omega_1, \omega_2, \omega_3, \omega_4)^T$$

(7)

B represents the evaluation result of the degree of “generalization, serialization, combination -levelization” of naval guns; $\overline{A}$ represents the element matrix composed of the standardized number coefficient $K_n$, the standardized type coefficient $K_r$, the generalized number coefficient $K_f$,
and the general type spectrum selection coefficient $K_p$; $\overrightarrow{W}$ represents the weighted weighting vector of the standardized number-of-pieces coefficient $K_i$, standardized type coefficient $K_z$, generalized number-of-pieces coefficient $K_p$, and generalized type spectrum selection coefficient $K_p$.

The definitions of the results of the "generalization, serialization, combination" evaluation are as follows:

Table 2. Thresholds of generalization, serialization, combination assessment

| Definition | Generalization, serialization, combination degree description | Field value |
|------------|---------------------------------------------------------------|-------------|
| B1         | Excellent                                                    | 0.95–1      |
| B2         | Good                                                         | 0.7–0.95    |
| B3         | Qualified                                                    | 0.50–0.7    |
| B4         | Relatively poor                                              | 0.333–0.5   |
| B5         | Poor                                                         | 0.167–0.333 |
| B6         | Extremely poor                                               | 0.167–0     |

3. Model Verification

In order to verify this method, this article takes a certain type of naval gun as an example, according to the part statistics and standardization degree statistics and description in the standardization review report of this type of naval gun, the parts statistics and standardization degree table shown in Table 3 are obtained.

Table 3. Parts Statistics and Standardization Degree Table

| Name              | Quantity | Total  |
|-------------------|----------|--------|
| Pieces            |          | $\sum_1=51782$ |
| Special parts $\sum e_j$ | 2090       |        |
| Unified $\sum t_j$ | 13976      |        |
| Standard Parts $\sum b_j$ | 32913    |        |
| Outsourcing $\sum w_j$ | 2803       |        |
| Number of varieties |          | $\sum z=8589$ |
| Special parts $\sum e_z$ | 1255       |        |
| Standard Parts $\sum b_z$ | 1998       |        |
| Outsourcing $\sum w_z$ | 249        |        |
| All types of spectrum parts $\sum p_{zi}$ | 7           |        |
| Types of common parts $\sum p_i$ | 14         |        |
| Generalization, serialization, combination coefficient | Standardized number coefficient($k_i$) | 0.9596 |
| | Standardized species coefficient($k_z$) | 0.8539 |
| | Generalized number of pieces coefficient($k_p$) | 0.9055 |
| | Universal spectrum selection coefficient($K_p$) | 0.5 |

According to the statistical analysis of the table, the following results are obtained:

1. Standardized number coefficient: $k_i=0.9596$;
2. Standardized species coefficient: $k_z=0.8539$;
3. Generalized number of pieces coefficient: $k_p=0.9055$;
4. Universal spectrum selection coefficient: $K_p=0.5$

Therefore, the four coefficient elements constitute a matrix: $A=(0.9596 \ 0.8539 \ 0.9055 \ 0.5)$.

According to the evaluation method, the importance and statistics are respectively analyzed, and the consistency analysis of the expert's rating opinions. After each recovery of the comment form, the consistency needs to be recalculated. According several rounds of consultation, the expert opinions tend to be consistent.
If the evaluation of the degree of “three transformations” of the project is carried out, after 5 experts’ importance scores and multiple comments, the following judgment matrix is formed:

\[
A_b = \begin{bmatrix}
1 & 2 & 3 & 5 \\
1/2 & 1 & 3 & 4 \\
1/3 & 1/3 & 1 & 2 \\
1/5 & 1/4 & 1/2 & 1
\end{bmatrix}
\]

Then this paper calculates the maximum eigenvalues of the judgment matrix \(A_b\) and their corresponding eigenvectors \(\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5\) respectively, and conducts consistency judgment to obtain the following results:

\[
\omega_1 = [0.4690 \ 0.3137 \ 0.1376 \ 0.0797]^T, \quad \lambda_1 = 4.0565, \ CR_1^b = 0.0212 \leq 0.1;
\]

\[
\omega_2 = [0.4690 \ 0.3137 \ 0.1376 \ 0.0797]^T, \quad \lambda_2 = 4.0565, \ CR_2^b = 0.0212 \leq 0.1;
\]

\[
\omega_3 = [0.4690 \ 0.3137 \ 0.1376 \ 0.0797]^T, \quad \lambda_3 = 4.0565, \ CR_3^b = 0.0212 \leq 0.1;
\]

\[
\omega_4 = [0.4690 \ 0.3137 \ 0.1376 \ 0.0797]^T, \quad \lambda_4 = 4.0565, \ CR_4^b = 0.0212 \leq 0.1;
\]

\[
\omega_5 = [0.4690 \ 0.3137 \ 0.1376 \ 0.0797]^T, \quad \lambda_5 = 4.0565, \ CR_5^b = 0.0212 \leq 0.1.
\]

After inspection, each judgment matrix meets the requirements of satisfactory consistency. The weights of the five experts are:

\[
\lambda_1^b = 0.1999, \quad \lambda_2^b = 0.2012, \quad \lambda_3^b = 0.1983, \quad \lambda_4^b = 0.2007, \quad \lambda_5^b = 0.1999.
\]

According to the model, the weighted geometric average method is selected to establish a comprehensive judgment matrix. The established comprehensive judgment matrix is:

\[
A = \begin{bmatrix}
1 & 3.2893 & 4.3164 & 5.7552 \\
0.3040 & 1 & 2.6994 & 4.5326 \\
0.2422 & 0.3705 & 1 & 2.8230 \\
0.1738 & 0.2206 & 0.3542 & 1
\end{bmatrix}
\]

The comprehensive ranking weight corresponding to the comprehensive judgment matrix is \(\omega = [0.5520 \ 0.2578 \ 0.1249 \ 0.0653]^T\). After the consistency check: the formula \(CR = 0.0158 < 0.1\), which conforms to the consistency check.

According to the comprehensive evaluation model of "three chemical", the current "generalization, serialization, combination" evaluation results of the naval gun are as follows:

\[
B = \tilde{A} \cdot \tilde{W} = [K_1, K_2, K_3, K_4] \cdot (\omega_1, \omega_2, \omega_3, \omega_4)^T
\]

\[
=[0.9596 \ 0.8539 \ 0.9055 \ 0.5][0.5520 \ 0.2578 \ 0.1249 \ 0.0653]^T
\]

\[
=0.9596 \times 0.5520+0.8539 \times 0.2578+0.9055 \times 0.1249+0.5 \times 0.0653
\]

\[
=0.8956
\]

Through the method of this paper, it is obtained that the type of naval gun has a good degree of "generalization, serialization, combination", meets the requirements of standardization, and has a good degree of generalization, serialization and combination (modularization).

4. Conclusion

The "generalization, serialization, combination" requirements for naval guns and naval guns will be included as important indicators in the development of weapons and naval guns, and will be
regarded as one of the important contents of the evaluation of the naval guns during the development stage.

In this paper, the research on the evaluation model and method of naval gun's "tri-chemical" degree can be used as the evaluation of naval gun's "tri-chemical", which provides certain data support for the development and production of naval gun serialization development.

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