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Establishment and weight of supportability indicator system for marine power system using analytic hierarchy process

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Abstract. Supportability evaluation is widely uesd in marine power system which is the most important equipment in a ship or vessel since it can provide energy for other systems of the ship/vessel. Analytic hierarchy process (AHP) is an effective and useful method for supportability evaluation and indicator system establishment due to its simplicity and convenience. In this paper, a hierarchical structure of indicator system for marine power system is established based on AHP, and four judgement matrixes of the supportabilities are constructed. Then a calculation method of the maximum eigenvalue is introduced to solve the ranking weight vector of those matrixes which can determine the weight of the indicator system for supportability evaluation of marine power system. Consistency index and its evaluation method are given for checking the judgement matrixes and conclusions. Finally taking a ship's power system as an example, the above solutions were calculated and results show that APH can grantee the validity and accuracy of the establishment and application of the indicator system. lower hierarchies and indicators could be considered due to the growing demand of the mission and service of marine power system.

1. Introduction

Marine power system, such as heavy-duty gas turbo, diesel engine, steam turbine and their auxiliary system, is the most important equipment in a ship or vessel since it can provide energy for other systems of the ship/vessel. Therefore, the evaluation and analysis of its supportability is an effective way to ensure the stable operation and function of the systems and the ship/vessel [1-3].

However, evaluation and analysis of marine power system supportability depends on establishment and weight of indicator system which have many objectives and properties, and not only contains various parameters and data, but also has complicated hierarchies and structures.

There is a vast literature [4-10], most of which is concerned with many theories and methods of establishment and application for indicator systems. Among them, analytic hierarchy process is useful method for establishing the evaluation systems and weighting the supportability indicators. As the most important part in the indicator system establishment for the supportability evaluation of the marine power system, the hierarchical structure of AHP have characteristics as follows:

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(1) The hierarchical structure of AHP has dominance relations in terms of top to bottom which are similar to the relations between sets, subsets and elements [4].

(2) The hierarchy amount of the hierarchical structure of AHP is unlimited and depends on the need of decision analysis for the purpose of solving concrete problems. Generally, the number of the element of the highest hierarchy is only 1 and the number of the element of the other hierarchies is less than 9, based on the consideration of the consistency for the multiple comparison among same hierarchy elements [5]. A hierarchy could be further divided into many sub-hierarchies when this hierarchy has excessive elements, so the element amount limit of a hierarchy could hardly cause the difficulty for the establishment of hierarchical structure of AHP [6].

(3) The correlation degrees between the different hierarchies are much greater than those between the different elements of the same hierarchy. Ordering principles of feedback system should be preferentially considered, when the basic ordering principles of AHP are not applicable if the correlation degrees between the different elements of the same hierarchy are too large to be ignore [7].

Therefore, the locations of the hierarchies must be determined, while the locations of the elements of the same hierarchy are unnecessary [8]. The establishment of the hierarchical structure of AHP has good flexibility and robustness, because the influence of the variation for the hierarchical structure is limited when an element of a hierarchy changes [9]. The decision objective of AHP can be derived by multi-hierarchical analysis and evaluation from top to bottom, so the partial judgments about some elements or/and a hierarchy has less influence on the decision objective comparing other methods [10]. Thus, AHP is a practical and effective method for determining the weights of the evaluation indicators.

Accordingly, the aim of this paper is to develop a better method in the establishment and application of the indicator system for supportability evaluation by using AHP, due to more safety and stable operating for marine power system.

2. Method and model

In this section, an analytic method of indicator system establishment for supportability evaluation of marine power system is introduced. Based on analytic hierarchy process, a hierarchical structure of the indicator system is established, and the judgement matrix of AHP is derived. For solving the problem of indicator weight, a calculation method is given by the maximum eigenvalue of the judgement matrix of AHP and consistency check.

2.1. Hierarchical structure

The construction procedures of hierarchical structure based on AHP are as follow: First, the whole problem of the indicator weights can be decomposed into many smaller and smaller parts, and one part has one element. Second, those elements are classified as different teams depending on their properties. As analytical criterion, the elements of the same hierarchy dominate the elements of the sub-hierarchy and are dominated by the elements of the upper-hierarchy. Thus, the dominance relation of hierarchical structure of AHP is established from top to bottom. Last, the highest hierarchy, which has only 1 element, is the decision objective or satisfactory result generally. The hierarchical structure of AHP is shown in Figure 1.

The intermediate hierarchies are the criteria and sub-criteria of the supportability evaluation, such as the parameters of the supportability of marine power system. The lowest hierarchy contains the evaluation methods and the data of supportability parameters. The dominance relations of the elements in the different hierarchies are not absolutely corresponding, so an element of the hierarchy could not dominate all the elements of the sub-hierarchy.

The hierarchical structure of the evaluation indicator of a marine power system and the parameter symbols have been performed with the following data in Table 1. The supportability of the power system A is the objective and its sub-hierarchy contains three criteria that are management supportability A_1, supply supportability A_2 and technique supportability A_3. The management supportability A_1 has three indicators: management staff A_{11}, management system A_{12} and management plan A_{13}. The supply supportability A_2 has three indicators: supply staff A_{21}, supply system A_{22} and supply plan A_{23}. The technique supportability A_3 has three indicators: technique staff A_{31}, technique system A_{32} and technique plan A_{33}.

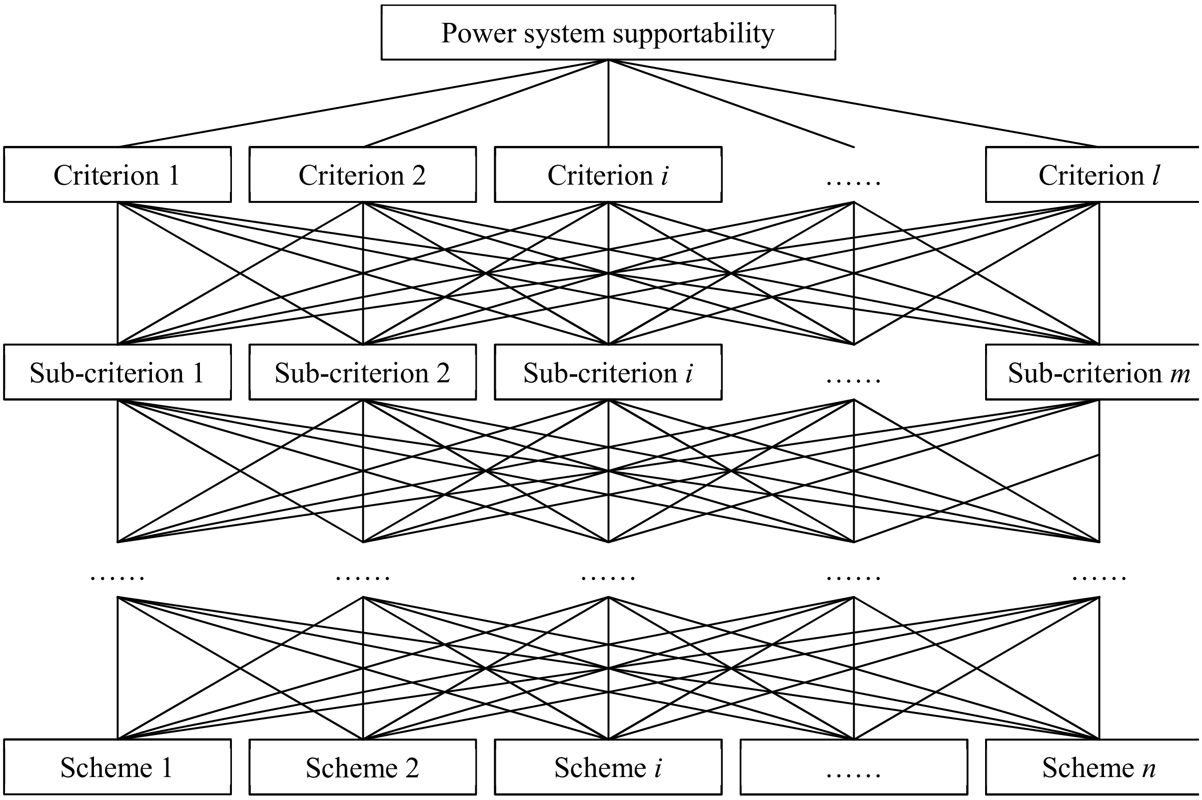

Figure 1. The hierarchical structure of AHP.

Table 1. The hierarchical structure of the supportability evaluation indicator of the power system.

Objective	Criterion	Indicator
Supportability (A)	Management supportability (A_1)	Management staff (A_{11}) Management system (A_{12}) Management plan (A_{13})
	Supply supportability (A_2)	Supply staff (A_{21}) Supply system (A_{22}) Supply plan (A_{23})
	Technique supportability (A_3)	Technique staff (A_{31}) Technique system (A_{32}) Technique plan (A_{33})

2.2. Judgment matrix

The dominance relations of the elements between different hierarchies are determined by the hierarchical structure of AHP. Supposing the ith element in the kth hierarchy $A_i^{(k)}$ is an evaluation criterion and dominates the elements ($A_1^{(k-1)}, A_2^{(k-1)}, \ldots, A_n^{(k-1)}$) of the sub-hierarchy (the k-1th hierarchy). Then the weights of $A_1^{(k-1)}, A_2^{(k-1)}, \ldots, A_n^{(k-1)}$ can be determined by the relative importance between the elements of the k-1th hierarchy based on the criterion $A_i^{(k)}$ .When the comparison result between the ith element $A_i^{(k-1)}$ and jth element $A_j^{(k-1)}$ of the k-1th hierarchy is a judgement value $a_{ij}^{(k)}$, the judgement results of the degrees of importance using AHP can be classified as 9 degrees, which are called as proportion criteria that an effective method for quantifying human thinking and judgment. According to the matrix properties and proportion criteria, the judgement matrix can be expressed as

$$\boldsymbol{A}_i^{(k)} = \begin{pmatrix} 1 & a_{12}^{(k)} & \cdots & a_{1n}^{(k)} \\ 1/a_{12}^{(k)} & 1 & \cdots & a_{2n}^{(k)} \\ \vdots & \vdots & & \vdots \\ 1/a_{1n}^{(k)} & 1/a_{2n}^{(k)} & \cdots & 1 \end{pmatrix} \tag{1}$$

Where values of $a_{ij}^{(k)}$ are shown in Table 2.

Table 2. The judgement results of the degrees of importance using AHP.

degree	Implication
1	It represents the two elements are of equal importance.
3	It represents the former is more important than the latter.
5	It represents the former is obviously more important than the latter.
7	It represents the former is deeply more important than the latter.
9	It represents the former is extremely more important than the latter.
2/4/6/8	It represents the median of the above judgement.

The sequencing problem of the weights of the elements $A_1^{(k-1)}, A_2^{(k-1)}, \ldots, A_n^{(k-1)}$ can be solved for evaluating the supportability of the marine power system by developing the multiple comparison of $A_1^{(k-1)}, A_2^{(k-1)}, \ldots, A_n^{(k-1)}$ and solving the matrix eigenvalues. Supposing ranking weight vector is $\boldsymbol{w}_i^{(k)}$, the function of the ranking weight vector can be expressed as

$$\boldsymbol{A}_i^{(k)} \boldsymbol{w}_i^{(k)} = \lambda_{i,\max}^{(k)} \boldsymbol{w}_i^{(k)} \tag{2}$$

The judgement matrix $\boldsymbol{A}_i^{(k)}$ has the maximum eigenvalue which is unique. The ranking weight vector $\boldsymbol{w}_i^{(k)}$ of the judgement matrix $\boldsymbol{A}_i^{(k)}$ can be composed of the positive components which are unique also, so the ranking weight vector $\boldsymbol{w}_i^{(k)}$ can be expressed as

$$\boldsymbol{w}_i^{(k)} = \begin{pmatrix} w_{i1}^{(k)} & w_{i2}^{(k)} & \cdots & w_{in}^{(k)} \end{pmatrix}^{\mathrm{T}} \tag{3}$$

For solving the ranking weight vector $\boldsymbol{w}_i^{(k)}$, the elements $a_{ij}^{(k)}$ of the judgement matrix $\boldsymbol{A}_i^{(k)}$ should be normalized by column and then column vectors are expressed as

$$\boldsymbol{B}_i^{(k)} = \begin{pmatrix} \boldsymbol{b}_1^{(k)} & \boldsymbol{b}_2^{(k)} & \cdots & \boldsymbol{b}_n^{(k)} \end{pmatrix} \tag{4}$$

Where

$$\boldsymbol{b}_n^{(k)} = \sum_{i=1}^{n} a_{in}^{(k)} \begin{pmatrix} a_{1n}^{(k)} & a_{2n}^{(k)} & \cdots & a_{nn}^{(k)} \end{pmatrix}^{\mathrm{T}}$$

Adding the elements of the matrix $\boldsymbol{B}_i^{(k)}$ by row, normalizing the results and transforming to column vector, the ranking weight vector $\boldsymbol{w}_i^{(k)}$ can be derived and expressed as

$$\boldsymbol{w}_i^{(k)} = \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}^{(k)}} \left(\sum_{i=1}^{n} b_{i1}^{(k)} \quad \sum_{i=1}^{n} b_{i2}^{(k)} \quad \cdots \quad \sum_{i=1}^{n} b_{in}^{(k)} \right)^{\mathrm{T}} \tag{5}$$

The maximum eigenvalue $\lambda_{i,\max}^{(k)}$ of the judgement matrix $\boldsymbol{A}_i^{(k)}$ can be solved due to the ranking weight vector $\boldsymbol{w}_i^{(k)}$.Then the maximum eigenvalue $\lambda_{i,\max}^{(k)}$ of the judgement matrix $\boldsymbol{A}_i^{(k)}$ can be expressed as

$$\lambda_{i,\max}^{(k)} = \frac{1}{n} \sum_{j=1}^{n} \frac{\boldsymbol{A}_i^{(k)} \boldsymbol{w}_i^{(k)}}{w_{ij}^{(k)}} \tag{6}$$

2.3. Consistency check

The key indicator system can be verified through the consistency check of the judgement matrix $\boldsymbol{A}_i^{(k)}$. There is no need to check the consistency when the judgement matrix $\boldsymbol{A}_i^{(k)}$ is constructed. However, when the ranking weight vector $\boldsymbol{w}_i^{(k)}$ is derived, the judgement matrix $\boldsymbol{A}_i^{(k)}$ must has consistency to ensure the ranking weight vector $\boldsymbol{w}_i^{(k)}$ completely reflects the degrees of importance between the elements and avoids the error of the indicator weights. Therefore, the consistency index of the judgement matrix $\mathrm{CI}_i^{(k)}$ can be expressed as

$$\mathrm{CI}_i^{(k)} = \frac{\lambda_{i,\max}^{(k)} - n}{n-1} \tag{7}$$

Supposing a random matrix, its rank is same as the judgement matrix $\boldsymbol{A}_i^{(k)}$.Comparing the consistency index of the judgement matrix $\mathrm{CI}_i^{(k)}$ and the consistency index of the random matrix RI, the consistency ratio $\mathrm{CR}_i^{(k)}$ can be expressed as follow and the values of RI are shown in Table3.

$$\mathrm{CR}_i^{(k)} = \frac{\mathrm{CI}_i^{(k)}}{\mathrm{RI}} \tag{8}$$

Table 3. The values of the consistency index of the random matrix.

Matrix dimension	3	4	5	6	7	8	9	10
RI	0.58	0.94	1.12	1.24	1.32	1.41	1.46	1.49

For $\mathrm{CR}_i^{(k)} < 0.1$, the judgement matrix $\boldsymbol{A}_i^{(k)}$ is acceptable and can be solving the ranking weight vector $\boldsymbol{w}_i^{(k)}$ to weight the key indicator for the supportability evaluation of marine power system.

3. Case study

In this section, three judgement matrixes are be given to establish the indicator system for supportability evaluation of marine power system based on the hierarchical structure of AHP. Then the consistencies of the judgement matrixes are be check according to consistency ratio.

According to Equation 1 and Table 2, the judgement elements of three experts are shown in Table 4-Table 7. Then four sets of the judgement matrixes: power system supportability $\boldsymbol{A}^{(I)}$, management supportability $\boldsymbol{A}_1^{(II)}$, supply supportability $\boldsymbol{A}_2^{(II)}$ and technique supportability $\boldsymbol{A}_3^{(II)}$ are constructed as follow.

Table 4. The judgement matrix of the supportability by the evaluation of three experts.

Expert	Indicator	Management supportability	Supply supportability	Technique supportability
	Management supportability	1	1/5	1/3
E_1	Supply supportability	5	1	3
	Technique supportability	3	1/3	1
	Management supportability	1	1/3	1/3
E_2	Supply supportability	3	1	1
	Technique supportability	3	1	1
	Management supportability	1	1/6	1/4
E_3	Supply supportability	6	1	2
	Technique supportability	4	1/2	1

Table 5. The judgement matrix of the management supportability by the evaluation of three experts.

Expert	Indicator	Management staff	Management system	Management plan
	Management staff	1	5	1
E_1	Management system	1/5	1	1/3
	Management plan	1	3	1
	Management staff	1	4	2
E_2	Management system	1/4	1	1/3
	Management plan	1/2	3	1
	Management staff	1	8	3
E_3	Management system	1/8	1	1/6
	Management plan	1/3	6	1

Table 6. The judgement matrix of the supply supportability by the evaluation of three experts.

Expert	Indicator	Supply staff	Supply system	Supply plan
	Supply staff	1	1/7	1/3
E_1	Supply system	7	1	3
	Supply plan	3	1/3	1
	Supply staff	1	1/6	1/2
E_2	Supply system	6	1	1/4
	Supply plan	2	4	1
	Supply staff	1	1/8	1/3
E_3	Supply system	8	1	1/6
	Supply plan	3	6	1

Table 7. The judgement matrix of the supply supportability by the evaluation of three experts.

Expert	Indicator	Technique staff	Technique system	Technique plan
	Technique staff	1	5	3
E_1	Technique system	1/5	1	1/2
	Technique plan	1/3	2	1
	Technique staff	1	4	4
E_2	Technique system	1/4	1	1
	Technique plan	1/4	1	1
	Technique staff	1	5	2
E_3	Technique system	1/5	1	1/3
	Technique plan	1/2	3	1

$$\boldsymbol{A}^{(\mathrm{I})}(E_1)=\begin{pmatrix}1 & 1/5 & 1/3\\ 5 & 1 & 3\\ 3 & 1/3 & 1\end{pmatrix},\ \boldsymbol{A}^{(\mathrm{I})}(E_2)=\begin{pmatrix}1 & 1/3 & 1/3\\ 3 & 1 & 1\\ 3 & 1 & 1\end{pmatrix},\boldsymbol{A}^{(\mathrm{I})}(E_3)=\begin{pmatrix}1 & 1/6 & 1/4\\ 6 & 1 & 2\\ 4 & 1/2 & 1\end{pmatrix}$$

$$\boldsymbol{A}_1^{(\mathrm{II})}(E_1)=\begin{pmatrix}1 & 5 & 1\\ 1/5 & 1 & 1/3\\ 1 & 3 & 1\end{pmatrix},\ \boldsymbol{A}_1^{(\mathrm{II})}(E_2)=\begin{pmatrix}1 & 4 & 2\\ 1/4 & 1 & 1/3\\ 1/2 & 3 & 1\end{pmatrix},\ \boldsymbol{A}_1^{(\mathrm{II})}(E_3)=\begin{pmatrix}1 & 8 & 3\\ 1/8 & 1 & 1/6\\ 1/3 & 6 & 1\end{pmatrix}$$

$$\boldsymbol{A}_2^{(\mathrm{II})}(E_1)=\begin{pmatrix}1 & 1/7 & 1/3\\ 7 & 1 & 3\\ 3 & 1/3 & 1\end{pmatrix},\ \boldsymbol{A}_2^{(\mathrm{II})}(E_2)=\begin{pmatrix}1 & 1/6 & 1/2\\ 6 & 1 & 1/4\\ 2 & 4 & 1\end{pmatrix},\ \boldsymbol{A}_2^{(\mathrm{II})}(E_3)=\begin{pmatrix}1 & 1/8 & 1/3\\ 8 & 1 & 1/6\\ 3 & 6 & 1\end{pmatrix}$$

$$\boldsymbol{A}_3^{(\mathrm{II})}(E_1)=\begin{pmatrix}1 & 5 & 3\\ 1/5 & 1 & 1/2\\ 1/3 & 2 & 1\end{pmatrix},\ \boldsymbol{A}_3^{(\mathrm{II})}(E_2)=\begin{pmatrix}1 & 4 & 4\\ 1/4 & 1 & 1\\ 1/4 & 1 & 1\end{pmatrix},\boldsymbol{A}_3^{(\mathrm{II})}(E_2)=\begin{pmatrix}1 & 5 & 2\\ 1/5 & 1 & 1/3\\ 1/2 & 3 & 1\end{pmatrix}$$

Taking the judgement of expert 1 as an example, the matrix $\boldsymbol{B}_i^{(k)}$ can be derived as follow according to Equation 4.

$$\boldsymbol{B}^{(\mathrm{I})}(E_1)=\begin{pmatrix}0.111 & 0.130 & 0.077\\ 0.556 & 0.652 & 0.692\\ 0.333 & 0.217 & 0.231\end{pmatrix},\ \boldsymbol{B}_1^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.455 & 0.556 & 0.429\\ 0.091 & 0.111 & 0.143\\ 0.455 & 0.333 & 0.429\end{pmatrix}$$

$$\boldsymbol{B}_2^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.091 & 0.097 & 0.077\\ 0.636 & 0.678 & 0.692\\ 0.273 & 0.226 & 0.231\end{pmatrix},\ \boldsymbol{B}_3^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.652 & 0.625 & 0.667\\ 0.130 & 0.125 & 0.111\\ 0.217 & 0.250 & 0.222\end{pmatrix}$$

Combing the four matrixes above and Equation 5, the ranking weight vectors and eigenvalue vectors of the judgement matrixes are given as follow.

$$\boldsymbol{w}^{(\mathrm{I})}(E_1)=\begin{pmatrix}0.106\\ 0.633\\ 0.261\end{pmatrix},\ \boldsymbol{w}_1^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.480\\ 0.115\\ 0.406\end{pmatrix},\boldsymbol{w}_2^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.088\\ 0.669\\ 0.243\end{pmatrix},\boldsymbol{w}_3^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.657\\ 0.112\\ 0.231\end{pmatrix}$$

$$\boldsymbol{\lambda}^{(\mathrm{I})}(E_1)=\begin{pmatrix}0.320\\ 1.946\\ 0.790\end{pmatrix},\ \boldsymbol{\lambda}_1^{(\mathrm{II})}(E_1)=\begin{pmatrix}1.461\\ 0.346\\ 1.231\end{pmatrix},\boldsymbol{\lambda}_2^{(\mathrm{II})}(E_1)=\begin{pmatrix}0.265\\ 2.014\\ 0.730\end{pmatrix},\boldsymbol{\lambda}_3^{(\mathrm{II})}(E_1)=\begin{pmatrix}1.910\\ 0.359\\ 0.674\end{pmatrix}$$

The results of the consistency check for the judgement matrixes are shown in Table 8. All judgement matrixes based on the evaluation of expert 1 are positive reciprocal matrixes and their $\mathrm{CR}(E_1)$ are less than 0.1.

In the same way, two sets of weight vectors based on the evaluation of the expert 2 and expert 3 can be derived and the consistencies of those matrixes can be checked. All the judgement matrixes based on the evaluation of expert 1, expert 2 and expert 3 are acceptable.

$$\boldsymbol{w}^{(\mathrm{I})}(E_2)=\begin{pmatrix}0.096\\0.675\\0.229\end{pmatrix},\ \boldsymbol{w}_1^{(\mathrm{II})}(E_2)=\begin{pmatrix}0.531\\0.121\\0.348\end{pmatrix},\boldsymbol{w}_2^{(\mathrm{II})}(E_2)=\begin{pmatrix}0.076\\0.691\\0.233\end{pmatrix},\boldsymbol{w}_3^{(\mathrm{II})}(E_2)=\begin{pmatrix}0.679\\0.090\\0.231\end{pmatrix}$$

$$\boldsymbol{w}^{(\mathrm{I})}(E_3)=\begin{pmatrix}0.121\\0.524\\0.355\end{pmatrix},\ \boldsymbol{w}_1^{(\mathrm{II})}(E_3)=\begin{pmatrix}0.397\\0.117\\0.486\end{pmatrix},\boldsymbol{w}_2^{(\mathrm{II})}(E_3)=\begin{pmatrix}0.111\\0.721\\0.168\end{pmatrix},\boldsymbol{w}_3^{(\mathrm{II})}(E_3)=\begin{pmatrix}0.602\\0.144\\0.254\end{pmatrix}$$

Table 8. The consistencies of the judgement matrix based on the evaluation of the experts.

Matrix	Maximum eigenvalue	CI	RI	CR	Consistency
$\boldsymbol{A}^{(\mathrm{I})}(E_1)$	3.040	0.020	0.58	0.035	Acceptable
$\boldsymbol{A}_1^{(\mathrm{II})}(E_1)$	3.028	0.014	0.58	0.024	Acceptable
$\boldsymbol{A}_2^{(\mathrm{II})}(E_1)$	3.009	0.005	0.58	0.009	Acceptable
$\boldsymbol{A}_3^{(\mathrm{II})}(E_1)$	3.010	0.005	0.58	0.009	Acceptable
$\boldsymbol{A}^{(\mathrm{I})}(E_2)$	3.038	0.019	0.58	0.033	Acceptable
$\boldsymbol{A}_1^{(\mathrm{II})}(E_2)$	3.019	0.010	0.58	0.016	Acceptable
$\boldsymbol{A}_2^{(\mathrm{II})}(E_2)$	3.058	0.029	0.58	0.050	Acceptable
$\boldsymbol{A}_3^{(\mathrm{II})}(E_2)$	3.043	0.022	0.58	0.038	Acceptable
$\boldsymbol{A}^{(\mathrm{I})}(E_3)$	3.011	0.006	0.58	0.010	Acceptable
$\boldsymbol{A}_1^{(\mathrm{II})}(E_3)$	3.064	0.032	0.58	0.055	Acceptable
$\boldsymbol{A}_2^{(\mathrm{II})}(E_3)$	3.089	0.045	0.58	0.077	Acceptable
$\boldsymbol{A}_3^{(\mathrm{II})}(E_2)$	3.061	0.031	0.58	0.053	Acceptable

Four weight vectors of supportability indicator system for marine power system are given.

$$\boldsymbol{w}^{(\mathrm{I})}(E_1,E_2,E_3)=\begin{pmatrix}0.107\\0.607\\0.277\end{pmatrix},\ \boldsymbol{w}_1^{(\mathrm{II})}(E_1,E_2,E_3)=\begin{pmatrix}0.466\\0.118\\0.409\end{pmatrix}$$

$$\boldsymbol{w}_2^{(\mathrm{II})}(E_1,E_2,E_3)=\begin{pmatrix}0.091\\0.693\\0.212\end{pmatrix},\boldsymbol{w}_3^{(\mathrm{II})}(E_1,E_2,E_3)=\begin{pmatrix}0.645\\0.113\\0.238\end{pmatrix}$$

Then normalizing the vectors above, the weights of the indicators for the supportability evaluation of the marine power system are obtained and the indicator system is established. The relative weights and absolute weights are shown in Table 9.

$$\boldsymbol{w}^{(\mathrm{I})} = \begin{pmatrix} 0.108 \\ 0.613 \\ 0.280 \end{pmatrix}, \quad \boldsymbol{w}_1^{(\mathrm{II})} = \begin{pmatrix} 0.469 \\ 0.119 \\ 0.412 \end{pmatrix}, \quad \boldsymbol{w}_2^{(\mathrm{II})} = \begin{pmatrix} 0.091 \\ 0.696 \\ 0.213 \end{pmatrix}, \boldsymbol{w}_3^{(\mathrm{II})} = \begin{pmatrix} 0.648 \\ 0.114 \\ 0.238 \end{pmatrix}$$

Table 9. The indicator system for supportability evaluation of marine power system.

Objective	Criterion	Weight	Indicator	Relative weight	Absolute weight
A	A_1	0.108	A_{11}	0.469	0.051
			A_{12}	0.119	0.013
			A_{13}	0.412	0.045
	A_2	0.612	A_{21}	0.091	0.056
			A_{22}	0.696	0.426
			A_{23}	0.213	0.130
	A_3	0.280	A_{31}	0.648	0.181
			A_{32}	0.114	0.032
			A_{33}	0.238	0.067

4. Conclusion

The indicator system for supportability evaluation of marine power system can be established by analytic hierarchy process. Developing the hierarchical structure and constructing the judgement matrix play important roles in AHP, while solving the eigenvalue and check the consistency can grantee the validity and accuracy of the establishment and application of the indicator system. AHP is an effective and useful method for ensuring the stable operation and function of the systems and the ship/vessel.

Because the database of design and operation of the marine power system while be extended and updated furthermore by the growing demand of the mission and service, the lower hierarchies and indicators could be considered. New method for the weights of those additional indicators can be studied for improving the feasibility and advancement of the supportability evaluation.

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