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Studies on the Weight Algorithm on Seafarers' Competence Assessment Index

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Abstract: The purpose for seafarers' competence assessment is to evaluate the practical operational ability of the applicants and the weight of the index directly influences the accuracy of the assessment results. This paper takes the assessment of route making as an example, makes use of the analytic hierarchy process in determining the weight of the indexes to provide theoretical reference for the perfection of seafarers' competence assessment.

Key words: Seafarers, competence assessment, weight, algorithm, analytic hierarchy.

1. Introduction

Determining the weight of the indexes is an important and study-worthy process in establishing the assessment system. The present practice is usually organizing the evaluation meeting of the experts for finalization by means of discussion and consultation, which results in financial costs and opinions subjective and less reflective of the actual reality. The analytic hierarchy process was put forth by US operational research experts Saaty, T. L. et al. in 70's last century. This method organically joins qualitative and quantitative analyses and conducts quantitative treatment to those that are hard for directness and accuracy, with greater practicality. Route making is a skill to be commanded by deck officers and is one of the items to be assessed in seafarers' competence certification, aiming at assessing the use of maritime publications in Chinese and English and the ability in route making in certain areas. This paper, taking the competence assessment of route making as an example, introduces the modeling process in determining the weight algorithm using the analytic hierarchy process.

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2. Establishing the Assessment Index System

In accordance with the STCW Convention and the "Syllabus for seafarers' competence examination" issued by the Ministry of Transport, PRC, the factors concerning the competence assessment on route making are divided into five aspects: resource, safety, economy, plotting and report.

"Resource" is the base for route making. The deck officer responsible for route making should be familiar with bridge resources and capable for correct selection and use. When determining the assessment factors for this item, the author takes into consideration the following aspects, whether the charts for selection are adequate, whether having conducted effective inspection on the application of the charts, whether the maritime publications are ready, whether having conducted effective inspection on the application of the maritime publications.

"Safety" is the principle for route making. There may be lots of factors influencing the safety of route and this paper tries to assess the deck officers' abilities in determining the off shore distance of the route, distance away from the isolated dangerous objects, handling of the incompleteness water depth on sea charts, route making in restricted areas and the use of ship's routing, etc.

"Economy" is the requirement for route making. On basis of ensuring the safety of navigation, the requirement is the shortest endurance. The aim is to assess the deck officers' use of recommended or experienced routes, abilities in choosing the rhumb line and great circle route and those in fixing the critical turning points.

"Plotting" is the principal part for route making. By means of plotting, the deck officers mark the route made and necessary notes on the charts for guiding the navigation of the ship. The deck officers are required for completeness and accuracy of the contents, facilitated and orderly activity and well-organized and pleasing interface.

"Report" is the reproduction of the route making process. As a supplementation of the chart plotting, route making report records the contents that escape the charts and in the practical operation of ships, the PSC also incorporates it in the contents for inspection. The concrete requirements for route making reports include the completeness of contents, applicability of information and standardization of filling.

The categorization of the assessment indexes on route making forms the following hierarchical structure in Table 1.

3. Constructing the 2-2 Judgment Matrix

3.1 Statistics

Experienced captains familiarized in seafarers' training and management, maritime educational experts qualified as assessors and shipping specialists are chosen as the statistical samples. In the design of the questionnaires, the 9 level hierarchy is set as the assignment criteria for 2-2 importance comparison between the indexes and meanings represented by the 9 level hierarchy is indicated in Table 2.

3.2 Constructing the Judgment Matrix

Eliminating the ineffective questionnaires and requiring the average value of the data in the questionnaires, refer to Table 3.

Constructing the judgment matrix, as:

Table 1 Three level indexes on route making.

u quality of route making																	
u_1 resources				u_2 safety				u_3 economy				u_4 plotting			u_5 report		
u_{11}	u_{12}	u_{13}	u_{14}	u_{21}	u_{22}	u_{23}	u_{24}	u_{25}	u_{31}	u_{32}	u_{33}	u_{41}	u_{42}	u_{43}	u_{51}	u_{52}	u_{53}
Selection of charts	Inspection of charts	Selection of publications	Inspection of publications	Off shore distance	Distance from isolated dangerous objects	Treatment of incompleteness of depth	Making in restricted waters	Use of ship's routing	Recommended (Customatory) route	Rhumb line and great circle route	Fixing route points	Completeness and accuracy	Facilitated and orderly activity	Well-organized and pleasing interface	Complete contents	Applicability of information	Standardization of filling

Table 2 Comparison scale for judgment matrix.

Scale a_{ij}	Meaning
1	Factor U_i is as important as factor U_j
3	Factor U_i is a bit more important than factor U_j
5	Factor U_i is more important than factor U_j
7	Factor U_i is much more important than factor U_j
9	Factor U_i is extremely more important than factor U_j
2, 4, 6, 8	Indicating the medium value of the above adjacent judgment

And satisfies $a_{ij} = 1/a_{ji}$.

Table 3 The data in the questionnaires.

	Resource	Safety	Economy	Plotting	Report
Resource	1	1/2	6	2	4
Safety	2	1	9	5	7
Economy	1/6	1/9	1	1/4	1/4
Plotting	1/2	1/5	4	1	1/2
Report	1/4	1/7	4	2	1

$$A=\begin{pmatrix} 1 & 1/2 & 6 & 2 & 4 \\ 2 & 1 & 9 & 5 & 7 \\ 1/6 & 1/9 & 1 & 1/4 & 1/4 \\ 1/2 & 1/5 & 4 & 1 & 1/2 \\ 1/4 & 1/7 & 4 & 2 & 1 \end{pmatrix}$$

4. Calculating the Relative Weight

Using the relevant knowledge of matrix to solve the matrix eigenvalue and the solved eigenvalue is the relative weight of the matrix elements. This method is precise in calculation but sophisticated. But the operations research provides us with a convenient and practical solving method of the approximate value.

4.1 Solve the Sum Total of Each Column in Determining the Matrix

It is referring to Table 4.

4.2 Each Element of the Judgment Matrix Is Divided by Its Corresponding Column Sum Total, the Matrix Composed of the Results Is Called the Standard Relative Matrix

$$B=\begin{pmatrix} 0.255 & 0.256 & 0.250 & 0.195 & 0.314 \\ 0.511 & 0.512 & 0.375 & 0.488 & 0.549 \\ 0.043 & 0.057 & 0.042 & 0.024 & 0.020 \\ 0.128 & 0.102 & 0.167 & 0.098 & 0.039 \\ 0.064 & 0.073 & 0.167 & 0.195 & 0.078 \end{pmatrix}$$

4.3 Calculating the Average Value of Each Line of the Relative Matrix and the Average Value Is the Relative Weight of the Elements, as Indicated in Table 5

That is, the relative weight of resource, safety, economy, plotting and report are respectively 0.254, 0.487, 0.037, 0.107, 0.115 and the sum total of weight is 1. The eigenvector of the judgment matrix is,

$$W=(0.254 \quad 0.487 \quad 0.037 \quad 0.107 \quad 0.115)^T.$$

4.4 Testing of the Consistency

The judgment matrix is formed by the subjective judgment of people's past experience and it can not ensure the consistency. Therefore, it is necessary to render consistency test on the positive and negative matrixes.

(1) Calculating the max characteristic root of judgment matrix:

$$\lambda_{\max}=\sum_{i=1}^{n}\frac{(AW)_i}{nW_i}=5.278$$

(2) Calculating the consistency index of the judgment matrix:

$$CI=\frac{\lambda_{\max}-n}{n-1}=\frac{5.278-5}{4}=0.070$$

When $CI=0$, the judgment matrix has the total consistency. The larger the CI, the less consistency of the matrix.

(3) Calculating the random consistency ratio of the judgment matrix

$$CR=CI/RI=0.070/1.12=0.062$$

For the hierarchical matrix from levels 1 to 9, the *RI* is respectively indicated as in Table 6.

(4) Conclusion

When CR ≤ 0.10, the judgment matrix has the satisfactory consistency. Otherwise, it is necessary to adjust the judgment matrix until it satisfies the inspection.

In accordance with the foregoing modeling steps for solution, resulting in, the weight orders of $u_{11}, u_{12}, u_{13}, u_{14}$ against u_1 are 0.574, 0.222, 0.126, 0.077; the weight orders of u_{21}, u_{22}, u_{23}, u_{24}, u_{25} against u_2 are 0.089,

Table 4 Solve the sum total of each column in determining the matrix.

	Resource	Safety	Economy	Plotting	Report
Resource	1	1/2	6	2	4
Safety	2	1	9	5	7
Economy	1/6	1/9	1	1/4	1/4
Plotting	1/2	1/5	4	1	1/2
Report	1/4	1/7	4	2	1
Colum sum total	3.917	1.954	24	10.25	12.75

Table 5 Calculating the average value of each line of the relative matrix and the average value is the relative weight of the elements.

	Resource	Safety	Economy	Plotting	Report	Line average value
Resource	0.255	0.256	0.250	0.195	0.314	0.254
Safety	0.511	0.512	0.375	0.488	0.549	0.487
Economy	0.043	0.057	0.042	0.024	0.020	0.037
Plotting	0.128	0.102	0.167	0.098	0.039	0.107
Report	0.064	0.073	0.167	0.195	0.078	0.115

Table 6 The average random consistency ratio of the judgment matrix from levels 1 to 9.

Levels	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

0.464, 0.044, 0.201, 0.201; the weight orders of u_{31}, u_{32}, u_{33} against u_3 are 0.700, 0.194, 0.107; the weight orders of u_{41}, u_{42}, u_{43} against u_4 are 0.581, 0.309, 0.110; the weight orders of u_{51}, u_{52}, u_{53} against u_5 are 0.075, 0.027, 0.010. The final summary calculation results in that, the total weights of u_{11}, u_{12}, u_{13}, u_{14}, u_{21}, u_{22}, u_{23}, u_{24}, u_{25}, u_{31}, u_{32}, u_{33}, u_{41}, u_{42}, u_{43}, u_{51}, u_{52}, u_{53} in the assessment index system of route making are respectively 0.146, 0.056, 0.032, 0.020, 0.044, 0.226, 0.021, 0.098, 0.098, 0.026, 0.007, 0.004, 0.062, 0.033, 0.012, 0.077, 0.028, 0.010, with the sum total of the weight as 1.

5. Conclusion

The method aims at solving the most suitable index weights within the allowable scope to bring the assessment result close to objectiveness, authenticity and effectiveness. The calculation makes use of computer language programming.

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