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Multi-Objective Green Ship Routing Based on Fuzzy Hierarchy Analysis and Ant Colony Algorithm

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Abstract. From the perspective of green operations, establishing an indicator system of multi-objective shipping arrangement which took into account the technical, economic, environmental and other factors, gave the judgment matrix of advanced technology, economic rationality, Environmental coordination and target layer consistency by using the method of Fuzzy Analytic Hierarchy Process. According to the fuzzy consistent judgment matrix, calculated the relative importance weights coefficient of each index of the criterion layer with respect to the target layer. According to multi-route and multi-boat liner shipping problems to establish mathematical model of multi-objective shipping route arrangement .For the multiple variables and multiple constraints problems of this model to give Ant Colony Optimization Model that suitable for liner shipping, and finally by comparing example with single-objective shipping arrangement and existing scheduling mode demonstrated the effectiveness of the proposed method, providing a new way for green operations.

Keywords: ant colony algorithm, fuzzy, green shipping, hierarchy analysis, ship routing

1 Introduction

To meet the requirements of green operations and in the course of operation of the ship not only to consider the coordination of the environment, but also should analyze the degree of application of economic rationality and advanced technologies. There are many factors affecting the operation of the ship green degree, in many factors, some are independent, some are closely, complex relationships and mutual restraint, various factors on the degree of the impact of the ship green operations also vary. Therefore, based on the evaluation purpose of this article to analyze the impact of each evaluation factor to the results, selecting these factors of good representative and deterministic which are certain differences between the ability and independent from each other to compose evaluation system. To make the green degree evaluation index system is more scientific and reasonable to improve the scientific evaluation of green, reliability and operability, this paper proposes to use the fuzzy analytic hierarchy process to build the weight coefficient of ship green degree evaluation index system.

Existing liner shipping companies generally have their own fleets, often arrange multiple boats operating on a number of routes, liner on each route daily maximum operating time is fixed, on each route required number of daily flights is fixed, sailing time and stop time of each ship on each route are to determine value, so in this case, there are thousands of scheduling scheme meet the requirements, but passenger transport companies how to find the optimal scheduling scheme from their own point of view, this need to be solved by constructing a mathematical model and to complete it.

In recent years, scholars have carried out more in-depth studies on the ship transportation by using

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many kinds of research methods. But there is little research on liner shipping. Dynamic programming is used to establish liner scheduling model with a better scheduling strategy is formulated with time window constraints by Ting etc. Mixed integer linear programming model to describe the ship scheduling and cargo path planning problems is established by Agarwal and other, etc. However, most of the research only considers the cost minimization, while ignoring the environmental factors in the scheduling objective. Based on green degree index optimization model is proposed to combine with liner shipping actual situation and existing related models. And the model is solved by ant colony algorithm.

2 Multi-Objective Ship Routing Index System

The condition of fleet capacity technology, operating economy, and environment factors etc, are mainly considered for fleet planning [1].

2.1 The Development of Marine Technology

Technical indicators should reflect advanced technology of the capacity type. Such as whether capacity type is environmentally friendly or not, how fast, whether manipulate is flexible or not, whether it is comfortable for the liner, etc.

2.2 Ship Operating Economy

The economy mainly includes the ship operating expenses, investment cost of new ships, ship's operating revenue and market trade demand and other factors.

Starting at the end of the last century, more and more enterprises pay attention to the economic impact on the whole fleet planning, even if the various technical performance and technical indicators of the fleet can meet the requirements of ship's normal operation, but because of shipping market, operating routes, and many other factors to make the operating economic effect poor. The shipping companies will bear greater economic losses if continue to use the existing ship or fleet planning model. So it is necessary to update the ship to meet the need of the market.

Economic indicator mainly reflects the profitability of the capacity type, mainly determined by the operating profit within the unit time of the capacity type. It is reflected from two aspects: transportation costs and transportation revenue.

2.3 Environmental Factors

But as more and more serious environmental pollution of ship, the ship's environmental performance requirements will continue to increase, there have been more and more attention on the environment-friendly of ship in society. Just considering the technical performance and economic efficiency of the ship during fleet planning is clearly not enough environmental factors will also be an important factor in the impact of the ship update. Environmental factors mainly refer to the environment coordination of the ship, that ship friendliness to the environment, embodied in aspects of ship pollution on the environment, resources and energy efficiency, and efficiency of the use of various social resources.

Evaluation index system of green ship should comprehensively and systematically cover all stages of different processes based on the definition and the connotation. The index parameters should be representative, rationality and availability to ensure the objectivity and accuracy of the evaluation and also make the evaluation process is easy to operation. The evaluation index is not the more the better. But evaluation must be able to represent the environmental impact behavior to make evaluation index result objective.

Index system is the basis of quantitative evaluation ship green degrees. Ship green degree evaluation result relies heavily on the reasonable and perfection of the index system.

According to the green shipping characteristics analysis, constructed the specific parameters of indicators under marine environment coordination as shown in Fig. 1.

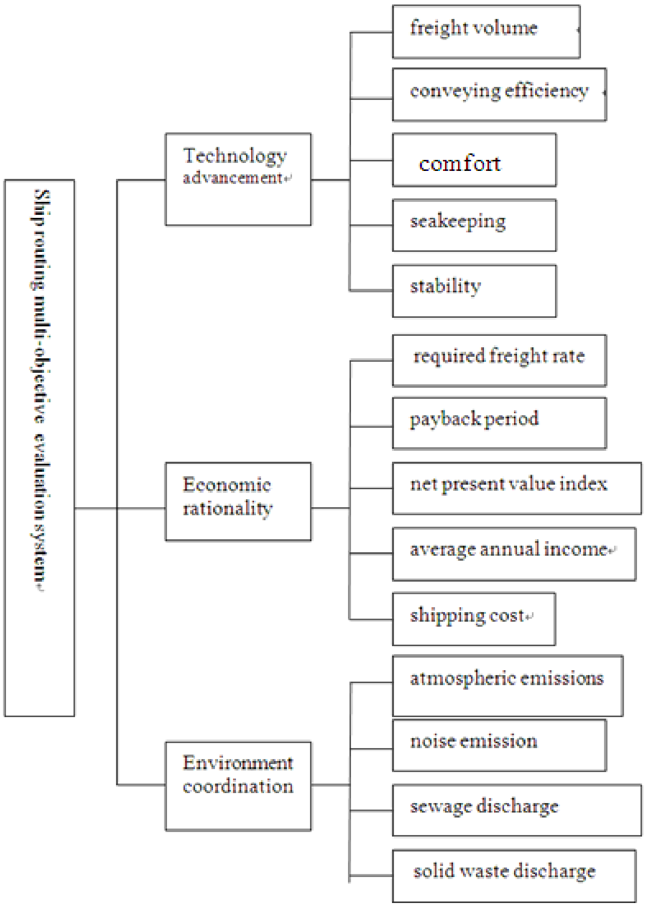

Fig. 1. Multi-objective evaluation index system of green liner scheduling

3 Fuzzy AHP Determine Weight Coefficient

An important step of the multi-objective decision is to determine evaluation index weights. Because of the pure quantitative multi-objective decision-making result value is the basic idea of multi-objective decision. By using a certain rules, technology, methods to each target of the actual value or utility values translates into a comprehensive value. Using a certain technology, methods to multi-objective decision problem changes into a single objective decision making problem. Then, according to the principle of single objective decision makes the decisions. Index weight in the evaluation process is a reflection of different important degree, is a comprehensive measures with subjective evaluation and objective reflection to the index relatively important degree. Plays a quite important role for the scientific rationality of the result of the evaluation is whether the weight assignment reasonable. If the weight of one factor changes, evaluation results will be affected. So weight assignment must be objective and scientific.

Analytic hierarchy process (AHP) is T.L. Saaty first proposed, this method is a quantitative and qualitative analysis combining to the multi-objective decision-making method. The method can effectively analyze the sequence relation between target rule system. Comprehensive effectively measures the judgment and comparison of the decision makers. Because the system is simple and practical, it is more and more widely used in many aspects, such as society, economy, and management.

But in order to improve the problems such as the difference between the judgment consistency and matrix consistency and the difficulty of the consistency check. The fuzzy analytic hierarchy process is used for green ship routing optimization problem.

3.1 Principles of Determining Weight

System optimization principle. In the evaluation index system, every index has its own role and contribution. Therefore, deal with the relation between each evaluation index not only from a single index, the weight distribution should be reasonable when determining weights. Weight option should follow the principle of system optimization to pursuit the overall optimization. Under the guidance of this principle, the evaluation index system of the evaluation indexes were analyzed, weigh the role and effect of the respective to the whole, then judge their relative importance. Determine the weights of each, not evenly distributed, nor one-sided emphasis on single index optimization, and ignore other aspects of development .In the practical work, each weight should play its own role.

Subjective intention and objective conditions combining principle. Evaluation index weights reflect the evaluators' guiding purpose and values. When they perceive that a target is very important, it is necessary to highlight the role and give a larger weight to the index. But the reality is often not satisfactory. Because some questions must be consider. (1) The balance between the same industry and the same work. (2) The particularity of society and enterprises. (3) The history and practical situation. Therefore, the reality must be considered to combine the intention and reality.

Democracy and centralization combination principle. The weight is a recognition of the importance of the evaluation index, is the quantization of the qualitative judgment which is often influenced by subjective factors. Everyone has their own points of view and often is not the same. In those some is reasonable composition also other is personal values, skills and attitudes of prejudice. Which requires the principle of group decision, focus on the opinions of the relevant staff complement each other, forming a unified plan. The following benefits if democracy and centralization combination. The problem can be fully considered and the weight allocation more reasonable and can prevent the one-sidedness. (2) The contradiction of the disagreement can be more objective to coordinate. The evaluation is strong persuasive after some discussion, consultation, investigation. Then can eliminate a lot of unnecessary disputes in advance. (3) This is a way to participate in the management, in the process of scheme discussion, everyone can put forward its own Suggestions, but also can further experience and understanding the evaluation purpose and target system, and in daily work, can work better at the scheduled target.

3.2 Fuzzy Consistent Matrix

If the structure matrix $B=(b_{ij})_{n\times n}$ meets $0\le b_{ij}\le 1\,(i=1,2,\cdots,n;j=1,2,\cdots,n)$ then B is a fuzzy matrix. If the fuzzy matrix $B=(b_{ij})_{n\times n}$ meets $b_{ij}+b_{ji}=1$ ($i=1,2,\cdots,n;j=1,2,\cdots,n$) then the fuzzy matrix B is fuzzy complementary matrix.

If the fuzzy complementary matrix $B=(b_{ij})_{n\times n}$ meets $\forall i,j,k$ and $b_{ij}=b_{ik}-b_{ik}+0.5$, then the fuzzy matrix B is fuzzy consistent matrix.

3.3 The Properties of Fuzzy Consistent Matrix

(1) $\forall i,(i=1,2,\cdots n)$, $b_{ii}=0.5$;

(2) $\forall i,j(i,j=1,2,\cdots n)$, $b_{ij}+b_{ji}=1$;

(3) The sum of the i th line and j th column of matrix B is n;

(4) The transpose matrix B^T and residual matrix B^C are fuzzy consistent matrix and $B^T=B^C$;

(5) Cross out any rows and the corresponding column from the matrix B, the matrix is still fuzzy consistent matrix;

(6) Matrix B meets the middle transitivity

When $\lambda\ge 0.5$, if $b_{ij}\ge\lambda, b_{jk}\ge\lambda$ then $b_{ik}\ge\lambda$;When $\lambda\le 0.5$,if $b_{ij}\le\lambda, b_{jk}\le\lambda$ then $b_{ik}\le\lambda$.

3.4 Calculation steps of Fuzzy AHP Method

Establish class hierarchy. Fuzzy AHP method took a complicated problem to de composed into target layer, criterion layer, index layer, even son index layer, through the analysis of the relationship between various influencing factors to building class hierarchy structure [2].

Construct the fuzzy judgment matrix [3]. Scaling is shown in Table 1.

Check the consistency of fuzzy judgment matrix. Accordingly adjust the fuzzy judgment matrix which does not satisfy the consistency. According to the properties of fuzzy consistent matrix, the specific steps to judgment of consistency and adjust are As follows:

Table 1. 0.1-0.9 scaling

Scale	Meaning
0.5	According to two factors compared with the same importance
0.6	compared to two factors, one factor is slightly more important than another factor
0.7	compared to two factors, one factor is more important than another factor obviously
0.8	compared to two factors, one factor is more important than another factor
0.9	compared to two factors, one factor than another factor is extremely important
0.1,0.2,0.3,0.4	The comparison, the importance of factors i and j is b_{ij}, then the factor j j than i is $b_{ji}=1-b_{ij}$

The first step, to determine a judgment accuracy higher and the importance score more precise elements, such as factor i .It importance compared with other factors are b_{i1},b_{i2},b_{i3} until b_{in}.

The second step, with $b_{i1},b_{i2},b_{i3}\cdots b_{in}$ respectively minus all lines the corresponding element, if the difference is constant then the bank don't need to be adjusted. Otherwise, it will be adjusted until $b_{i1},b_{i2},b_{i3}\cdots b_{in}$ minus the corresponding element is constant.

Hierarchical single sort. Get the relative importance weights of a certain level index to on a hierarchy. The sorting method was used to evaluate the relative importance weights. The specific calculation steps are as follows: firstly the sum of all elements on each row is calculated $\sum_{j=1}^{n} b_{ij}$ $i=1,2,\cdots n$. Set parameters α , α meets $\alpha \geq \frac{n-1}{2}$; according to the number n of factors, parameters α and $\sum_{j=1}^{n} b_{ij}$, $i=1,2,\cdots n$,The relative importance weights

$$\omega_i = \frac{\sum_{j=1}^{n} b_{ij}}{n\alpha} + \frac{1}{n} - \frac{1}{2\alpha},\ i=1,2,\cdots n.$$

Hierarchy total sorts. Based on hierarchical single sort, calculate the weights of index layer all factors relative to the target. Weight is the product of the weight of each index to the rule layer and the weight of the rule layer to the target layer [4].

4 Green Liner Scheduling Index Weight

4.1 Green Liner Scheduling Index Weight

In this paper, target layer is green scheduling optimization model. Rule layer includes three first-level indicators, i.e., economic rationality, technology advanced, environmental coordination [5].

4.2 To Construct Fuzzy Consistent Judgment Matrix

As much as possible in order to raise the scientific nature of the fuzzy consistent judgment matrix, Delphi method is used to set value for judgment matrix. The steps are as follows:

(1)The experts were composed of to fill out the questionnaire. For the formation of the judgment matrix, the importance questionnaire was formulated and chose professionals to form group to fill in the questionnaire by back to back form.

(2) The first round grading results was statistics, analysis. The results of judgment consistent can be directly used. And the consensus opinion was summarized and distributed to the panel members. The importance of the factors were assess according to collect opinions.

(3) To statistic and analyze the second round results. Importance of judgments is inconsistent results, using the score of frequency highest. Form the judgment matrix, consistency check was performed by using the properties of fuzzy consistent judgment matrix.

(4) Adjust the judgment matrix which had not through the consistency check and reconstruct fuzzy consistent judgment matrix.

The resulting structure of fuzzy consistent judgment matrix is shown in Table 2 to Table 5.

Table 2. Economic rationality fuzzy consistent judgment matrix

U_2	Required freight rate	Payback period	Net present value index	Average annual income	Ship cost
required freight rate	0.5	0.7	0.7	0.8	0.6
payback period	0.3	0.5	0.5	0.6	0.4
net present value index	0.3	0.5	0.5	0.6	0.4
average annual income	0.2	0.4	0.4	0.5	0.3
ship cost	0.4	0.6	0.6	0.7	0.5

Table 3. Technology advanced fuzzy consistent judgment matrix

U_1	Freight volume	Conveying efficiency	Comfort	Seakeeping	Stability
Freight volume	0.5	0.6	0.4	0.7	0.6
Conveying efficiency	0.4	0.5	0.3	0.6	0.5
Comfort	0.6	0.7	0.5	0.8	0.7
Seakeeping	0.3	0.4	0.2	0.5	0.4
Stability	0.4	0.5	0.3	0.6	0.5

Table 4. Environment coordinated fuzzy consistent judgment matrix

U_3	Atmospheric emissions	Noise emission	Sewage discharge	Solid waste discharge
Atmospheric emissions	0.5	0.4	0.7	0.6
Noise emission	0.6	0.5	0.8	0.7
Sewage discharge	0.3	0.2	0.5	0.4
Solid waste discharge	0.4	0.3	0.6	0.5

Table 5. The target layer consistency fuzzy judgment matrix

U	Economic	Technology	Environment
Economic	0.5	0.7	0.8
Technology	0.3	0.5	0.6
Environment	0.2	0.4	0.5

According to the above calculation steps, hierarchical single sort results are as follows:

The relatively important weight of the index criterion layer to the target layer according to the fuzzy consistent judgment matrix is:

$$W = [w_1, w_2, w_3]^T = [0.5, 0.3, 0.2]^T$$

According to the fuzzy consistent judgment matrix calculated the relative importance weights of index layer relative to the rule layer's are:

$$W_1 = [w_{11}, w_{12}, w_{13}, w_{14}, w_{15}]^T = [0.23, 0.18, 0.28, 0.13, 0.18]^T$$

$$W_2 = [w_{21}, w_{22}, w_{23}, w_{24}, w_{25}]^T = [0.28, 0.18, 0.18, 0.13, 0.23]^T$$

$$W_3 = [w_{31}, w_{32}, w_{33}, w_{34}]^T = [0.283, 0.35, 0.15, 0.217]^T$$

According to the results of single sort, calculation every index weight of index layer relative to the target layer, namely hierarchy total ordering. The calculation result was shown the most right column elements of Table 6.

5 Mathematical Model and Solution for Ship Routing

5.1 Mathematical Model

According to the importance of the target, to convert the multi-objective problem into a single objective problem by using the linear weighted method.

Table 6. Fuzzy AHP method hierarchy total sorting results

U	Economic 0.5	Technology 0.3	Environment 0.2	W
Required freight rate	0.23			0.115
Payback period	0.18			0.090
Net present value index	0.28			0.140
Average annual income	0.13			0.065
Ship cost	0.18			0.090
Freight volume		0.28		0.084
Conveying Efficiency		0.18		0.054
Comfort		0.18		0.054
Seakeeping		0.13		0.039
Stability		0.23		0.069
Atmospheric emissions			0.283	0.057
Noise emission			0.35	0.070
Sewage Discharge			0.15	0.030
Solid waste discharge			0.217	0.043

Build the mathematical model basic on the ship scheduling model [6-8]. The mathematical model is as follows:

The objective function:

$$\min \sum_{l=1}^{L} \sum_{i=1}^{m} \sum_{j=1}^{n} \alpha_l \cdot x_{ij} \cdot c_{ijl} \tag{1}$$

The constraints:

$$\begin{aligned} &\sum_{j=1}^{n} t_{ij} \cdot x_{ij} \le k_i \qquad i = 1 \cdots m \\ &\sum_{i=1}^{m} x_{ij} = q_j \qquad j = 1 \cdots n \\ &x_{ij} \ge 0, \text{and } x_{ij} \;\; is \;\; \text{int} eger \end{aligned} \tag{2}$$

where α_l is the weight coefficient of every index

x_{ij} is a variable, the number of round trip of *i* ship on *j* route

c_{ijl} is *lth* decision-making parameter values of *i* ship on *j* route

t_{ij} is once the operating time of *i* ship on *j* route

k_i is the most working time every day for the *i* ship

q_j is the number of flights a day for *j* route;

m for ship number

N for route number;

L as decision-making index number

5.2 Ant Colony Algorithm for Nonlinear Integer Programming

Ant colony algorithm can obtain the good simulation results for the complex group optimization problem in the way similar to the ant foraging. Ant colony algorithm's advantage lies in avoiding lengthy programming and planning. The program itself is based on a certain rule of random operation to find the best configuration. By the information principle of the ants searching for food, the program can constantly fix the original route to make the whole route shorter and shorter, so as to make the feasible solution converge to the optimal solution. These advantages are suitable for liner optimization scheduling problem.

Assume an integer programming model can be expressed as follows [9]:

$\min f(x_1, x_2, \cdots, x_n)$

$s.t. \quad a_i \le x_i \le b_i \quad i = 1,2,\cdots,n$

$x_i \in Z \quad j = 1,2,\cdots,n$

Where: Z as an integer space, a_i, b_i $(i = 1,2,\cdots,n)$ as an integer, $l_i = b_i - a_i + 1$ is the possible number.

The feasible solution space is shown in Fig. 2, x_i has l_i nodes, each variable taking a value to make up a solution in space. If x_i takes m_i nodes, then the corresponding solutions as follow [10]:

$(x_1, x_2, \cdots, x_n) = (a_1 + m_1 - 1, a_2 + m_2 - 1, a_3 + m_3 - 1, \cdots a_n + m_n - 1,)$

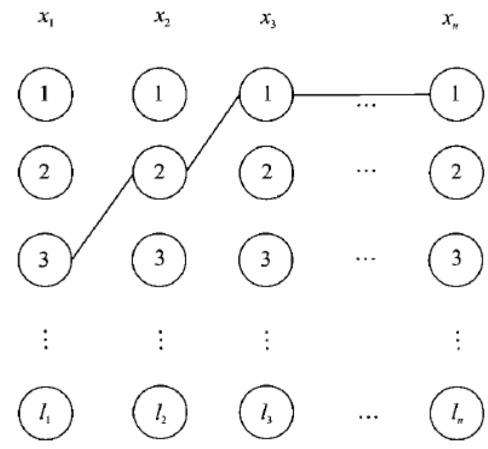

Fig. 2. Feasible solution space

N selected variables into n level decision making problems, the class *i* has l_i node. At first m ants is in the first stage. The probability of *j* selected *i* is

$$p_{ij} = \frac{\tau_{ij}}{\sum_{i=1}^{l_j} \tau_{ij}} \tag{3}$$

τ_{ij} is the draw strength of *i* node to *j* class. Update equations as follows

$$\tau_{ij}^{new} = \rho \tau_{ij}^{old} + \frac{Q}{f} \tag{4}$$

Where: ρ is the intensity attenuation coefficient, usually take about 0.5 ~ 0.9. Q is a normal number. f is the objective function value.

The pheromone in each path is same when the ant colony algorithm is initialized. The ants choose the path with equal probability. So that it is difficult to find a better path from large disorganized paths in a short period time. So speed of convergence is slow.

Solution of ant colony algorithm for nonlinear integer programming is as follows:

(1) $nc \leftarrow 0$ (nc is number of cycles). Give τ_{ij} the same numerical ode and produce a large number of paths (such as100), select the better from them (such as 30) [11]. The paths are left pheromone Q, P.

(2) The M ants are placed in the first stage.

(3) According to the transition probability p_{ij}, each ant selected a node in the class aimed each ant traveled n nodes;

(4) Calculate the objective function value f. If the function value is less than the given path then the attraction intensity is modified according to the update equation.

(5) If $nc \succ$ cycle number specified then stop running. According to τ_{ij} the node is selected (if $\tau_{i_0 j} = \max_i \tau_{ij}$, select the nodes i_0 in the j level) otherwise turn (2).

The original constraint equation as the penalty function was added to the original target for integer programming with constraints. Take into unconstrained optimization problem to solve.

5.3 Application of Ant Colony Algorithm in Ship Routing

Convert the multi-objective problem into single objective problem with linear weighted method according to the important of the target to construct the objective function of ant K [12, 13].

The mathematical model of the problem need to further process for the use of ant colony algorithm. Consider the N round-trip flights route l... N, and be used M ships for every round-trip flights. The structure was shown in Fig. 3. A space path is composed by taking a value for each path.

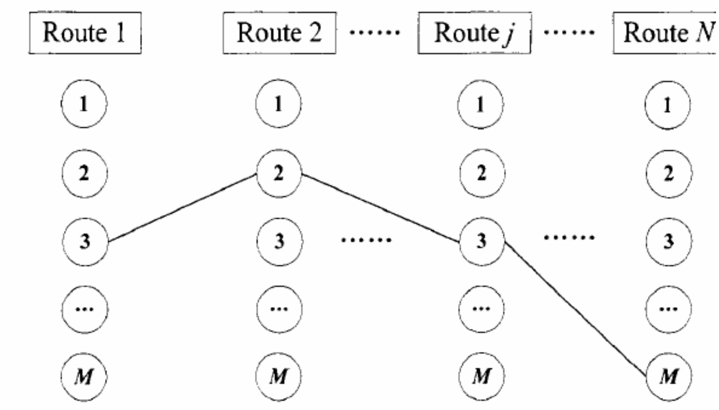

Fig. 3. Ship routing feasible solution space structure

At the beginning M node Ants random distribution on the M nodes of route l. Transition probability of ants select nodes in Route j for i:

$$p_{ij}=\begin{cases}\dfrac{\tau_{ij}}{\sum_{k=1}^{S}\tau_{ik}}, i\notin\left\{Route\ k\,\middle|\,matrix_{jk}=1, 1\le k\le j-1\right\}\\ 0 \quad \text{otherwise}\end{cases} \tag{5}$$

In the formula (5), $matrix$ is a 0-1 matrix which describes whether the time between two round-trip conflicts. $matrix_{jk}=1(0)$ shows that it exists conflict (otherwise) between j and k flights (otherwise) as shown in Fig. 4 and $matrix_{jj}=0$, $matrix_{jk}=matrix_{kj}$.

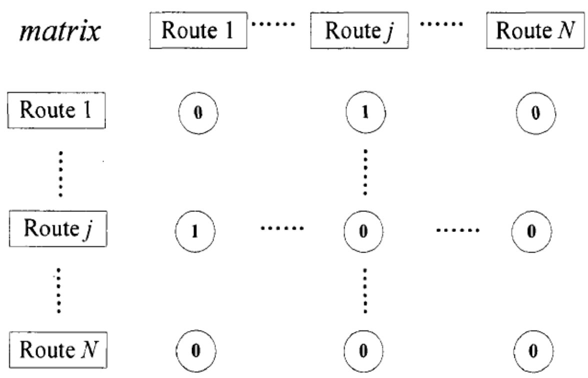

Fig. 4. The time conflict matrix about round trip

The pheromone update mechanism makes the pheromone update equation:

$$\tau_{ij}^{new}=\rho\cdot\tau_{ij}^{old}+\Delta\tau_{ij} \tag{6}$$

Where $\Delta\tau_{ij} = \sum_{k=1}^{Ants} \Delta\tau_{ij}^{k}$. It is the sum of all the pheromone which were left by the ants after Route j the i node.

And $\Delta\tau_{ij}^{k}$ is identified according to the formula (7).

$$\Delta\tau_{ij}^{k} = \begin{cases} Q / fval_{k}, & ant\ k\ though\ route\ j\ and\ i\ node \\ 0 & otherwise \end{cases} \tag{7}$$

Where Q is an appropriate constant and $fval_k$ is the objective function value of the ant K.

Pheromone evaporation mechanism. Make pheromone reservation coefficient.

ρ .

After every iteration, pheromone retention amount is $\rho \cdot \tau_{ij}^{old}$. In this way, the basic idea of the algorithm is that individual ants release certain amount pheromone on the path according to local renewal rule in the process of construction feasible solution. After iteration, ants will tend to choose the path with the pheromone intensity higher and the objective function value smaller and to make feasible solutions converge to the optimal solution.

6 Example

A high-speed passenger transport company was the research object which had six high-speed ships. The number were recorded as “1”, “2”, “3”, “4”, “5”, and “6”. They run on the A, B, C, and D routes. The basic parameters of each ship were different, so the ship voyage cost was the large differences on various routes. Operating costs is shown in Table 7.

Table 7. Operating costs (RMB/time)

	1	2	3	4	5	6
A route	3254.7	3677.86	2831.88	2826.89	3763.62	3680.21
B route	2607.01	2895.08	2268.98	2040.7	2701.09	2651.83
C route	3601.91	4112.09	3182.61	3180.91	4265.86	4220.55
D route	3927.76	4504.85	3486.34	3491.96	4677.87	4729.45

The operation parameters of each vessel are shown in Table 8.

Table 8. The operation parameters of each ship

Ship	V (kn)	FH (L/mile)	HFP (RMB/hour)	Class (number)
1	27	19.23	4101.76	304
2	29	21.83	5001.25	350
3	29	18.65	4272.72	232
4	29	18.48	4233.77	232
5	32	27.07	6843.30	326

The comfort is considered respectively from the cabin comfort, the seaworthiness of the ship and the ship noise three aspects. And fuzzy comprehensive evaluation method is used to quantify the comfort and the quantization value is shown in Table 9.

Table 9. Each ship comfort quantitative value

	1	2	3	4	5	6
Quantization value	0.85	0.79	0.58	0.58	0.8	0.5

Two kinds of calculation conditions were selected to shipping optimization. The first one is only consider the economic benefits of the optimal operation from the cost perspective. The second is not only to consider the economic, but also to consider technology and environmental factors at the same time so as to achieve the purpose of green ship operation.

Calculation state I: the objective function considering only the daily cost requires daily cost minimum; the optimization calculation was shown in Table 10.

Table 10. Final arrangements based on the minimum cost

	1	2	3	4	5	6
A route	10	2	0	0	0	0
B route	0	8	0	6	0	0
C route	0	0	8	4	0	0
D route	0	0	0	0	0	6
Voyage cost= 14657 (yuan/day)						

Calculation state II: the objective function considering green operation concept. In this calculation, economic, technical and environmental weights are 0.5, 0.3, and 02.

Calculated by using ant colony algorithm for numerical simulation, τ_{ij} =100, Q =2000, NC=200, m=30. The calculation results were shown in Table 11.

Table 11. Final arrangements based on green degree (cost 0.5, comfort 0.3, environment 0.2)

	1	2	3	4	5	6
A route	6	4	2	0	0	0
B route	6	4	0	0	4	0
C route	0	0	4	8	0	0
D route	0	0	4	0	2	0
Voyage cost=16872 (yuan/day)						

7 Conclusion

First, the optimization results under two conditions (Tables 10 and 11) and the existing scheduling time table were compared to find that the optimal scheduling results is feasible according to the existing scheduling time table operation which also explains ship optimization dispatch mathematical model applicability.

Through the demonstration results found that the operating costs was increase when decision makers were starting from the greenness comprehensive consideration economic, technical, comfort and environmental protection and other aspects. This was consistent with the facts situation which also explains the optimization scheduling model was reasonable. It is necessary to carry out comprehensive evaluation optimization with people more and more realizing the environment important. The operation of the ship was a complex process involving all aspects. Integrated optimization and demonstration was only the typical indicators in this paper. Further research is needed.

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