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Research on Total Revenue Optimization's Ship Maintenance Selection

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Abstract: This paper aims to establish a total revenue optimal model of operating ships when facing a maintenance requirement and cargo shipping opportunity under some limited conditions. In terms of influencing factors of analytical results, total shipping distance, sailing time and maintenance time are the main influence factors on total revenue.

Introduction

Economic benefit of shipping enterprise is extremely relative to revenue of shipping business and maintenance costs of ships maintenance. According to current prosperity degree of shipping market, the economic interests of shipping enterprise heavily depend on saving costs of operating and new high-technology application on ships maintenance. Therefore, the reasonable shipping lines and high-efficient maintenance methods of ships are contributed to promoting operating revenue and security.

Literature review

The maintenance costs of ships are an important part of operating costs that is directly relative to whole shipping enterprises' economic interests. Facing to different ages and types of ships maintenance requirement, the maintenance time and maintenance interval of ships are quite different. Currently, ships maintenance generally includes special inspection and annual inspection. In order to keep high profits of shipping enterprises in depressed market condition, most of enterprises usually select three methods: temporary maintenance, medium maintenance and heavy maintenance. Thus, they can ensure operating ships are in working order to meet recent shipping requirements. According to those reasons, a lot of researchers concentrate on relative optimization research fields, such as maintenance time, maintenance fees, maintenance location, shipping route selection and shipping opportunity costs.

Xiaojun Li[1] focuses on functional characteristics of semi-submerged maintenance ship to study optimum number allocation and maintenance location in competitive situation. Meanwhile, his research provides a time and economic impact model of latest time constraint condition on arrival time for semi-submerged maintenance ship task. Zhenyu Cao[2] establishes a nonlinear integer programming model and adopts hybrid genetic algorithm to solve the location problem of maintenance service centers. Ming Li[3] studies on traditional maximum coverage model for extended application range requirement and based on the theory of priority satisfaction to optimize the maximum maintenance facilities location model.

Peng Dong[4] mainly focuses on the unconcerned aspects of traditional model that including unconsidered requirement points outside the original service radius and response time. In terms of ships maintenance requirement, Dong provides a mixed algorithm, including genetic simulated annealing algorithm and BP neural network, to solve a comprehensive model of the maximum coverage location and temporal contentment function.

Ship maintenance costs and location selection optimal

As mentioned above, operating ships should be periodically inspected by lots of ships maintenance requirement. In the actual situation of shipping, shipping enterprises hardly divide maintenance costs categories by regular methods from minor repair, medium repair and overhaul. Generally, shipping enterprises usually adopt factory maintenance, crew repair and spare parts inventory to conduct maintenance costs classification[5].

According to previous collected data of research sample in shipping enterprises' annual profit, the factory maintenance costs occupy nearly 50% of total maintenance costs, the crew repair costs always keep at 26% of total maintenance costs, the spare parts costs of total maintenance costs is mainly 3% higher than crew repair costs. Meanwhile, shipping enterprises generally encourage those crew repair in reasonable range by themselves to achieve the aim of maintenance costs saving.

Facing to huge spending of ships maintenance, this paper mainly concentrates on reducing the number of maintenance times in factory, selecting a reasonable maintenance manufacturers and promoting crew's repair ability. Actually, the equipment of operating ships needs to be repaired in factory after a period of operation. This maintenance method not only solves the present equipment problems faced by operating ships, but also prevents future problems of equipment in operating ships. All in all, any operating ships of shipping enterprise needs to consider a large number of key factors comprehensively, including present location of ship, cargo shipping opportunity costs, the distance between maintenance location of factory and cargo destination of shipping, fuel costs, labor costs, maintenance service level and so on.

In accordance with those influencing factors, the research on optimization model will be built in following content. In the model, this paper assumes the operating ship has one opportunity of cargo shipping before maintenance in factory and does not consider next opportunity of cargo shipping. Then, this model exists N-th cargo shipping opportunities and M-th locations of maintenance factories. Therefore, the object function model is established as follow:

$$Max(E_{ij}) = (P_i + R_{ij} + R_i) - (F_{ij} + \frac{L_i + L_{ij}}{24\bar{V}} C'' + Q_{ij}) \tag{3-1}$$

$$F_{ij} = C' t_j + C_j \tag{3-2}$$

$$C_j = M_j + H_j \tag{3-3}$$

Constraint conditions：

$$t_i + \frac{L_i + L_{ij}}{24\bar{V}} \le T; i = 1,2,3,4...M;$$
$$Q_{ij} > 0; i = 1,2,3,4...N; \ j = 1,2,3,4...M; \tag{3-4}$$

E_{ij}-The total revenue of i-th cargo shipping opportunity subtracts the j-th ship maintenance costs in factory;

F_{ij}-The total maintenance costs in factory when the ship completes its i-th cargo shipping opportunity;

$C^{'}$ - A fixed costs of ships berthed;

t_j-Ship maintenance period of j-th repair factory;

C_j-Ship maintenance price of j-th repair factory;

M_j - Spare part costs of maintenance in factory;

H_j - Labor costs of maintenance in factory;

P_i - Revenue of each cargo shipping opportunity;

L_i - if study selects cargo shipping opportunity that represents the distance between ship current location and destination of i-th cargo shipping opportunity, otherwise, this symbol represents the distance between ship current location and repair factory location;

L_{ij}-The distance between the destination of i-th cargo shipping opportunity and j-th repair factory location;

$\bar{V}$ - Average speed of ship;

$C^{''}$ - Costs of ship sailing in everyday;

t_i-The destination berthing time (day) of i-th cargo shipping opportunity;

Q_{ij}-Incremental maintenance costs of j-th repair factory when the ship selects i-th cargo shipping opportunity;

R_i - Revenue approach of i-th cargo shipping opportunity in its destination that include competitively priced of spare parts, fresh water, fuel and lubricating oil.

R_{ij}-Revenue approach of i-th cargo shipping opportunity and j-th maintenance in factory have been finished.

T -Ship safety operation time (day).

Verification

For research requirement, this paper aims to assign assuming numbers to parameters mentioned above, meanwhile,It helps to understand the results of total revenue and main influencing factors of change trend based on the previous model 3-1. In table 1, table 2 and table 3, the parameters of present location of ship, maintenance time, berth time, the distance between cargo shipping port and repair factory, and other influencing factors are assigned numerical values.

Table 1. the distance from ship location to repair factory and cargo shipping destination respectively(nm=nautical miles)

	Repair factory 1	Repair factory 2	Repair factory 3	Cargo shipping port 1	Cargo shipping port 2
Ship	760 nm	790 nm	820 nm	960 nm	640 nm
Repair factory 1	-	470 nm	980 nm	720 nm	1180 nm
Repair factory 2	-	-	680 nm	1000 nm	520 nm
Repair factory 3	-	-	-	1350 nm	460 nm
Cargo shipping port 1	-	-	-	-	1150 nm
Cargo shipping port 2	-	-	-	-	-

At the same time, the average speed of ship is assumed 20 nautical miles per hour, and the sailing fixed costs and berth costs are given 20 ten thousand yuan per day and 12 ten thousand yuan per day separately. Moreover, the max safety operating time of ship before its need to be maintenance in factory is 6 days.

Table 2. Maintenance time and cargo shipping revenue (d=day,thy=ten thousand yuan)

	Repair factory 1	Repair factory 2	Repair factory 3	Cargo shipping port 1	Cargo shipping port 2
Maintenance time	6d	8d	7d	-	-
Berth time	-	-	-	1d	1d
Revenue of cargo shipping	-	-	-	610 thy	590 thy

Table 3. Sailing fixed costs, berth costs and maintenance costs

	Ship	Repair factory 1	Repair factory 2	Repair factory 3
Sailing fixed costs	20 thy	-	-	-
Berth costs (factory)	12 thy	6*12 thy	8*12 thy	7*12thy
Maintenance costs		75 thy	60 thy	70 thy
Total maintenance costs		147 thy	156 thy	154 thy

In terms of constraint condition of model, the time consumption results in table 4 of shipping and berth in any combination situation all comply with the rest time of safety shipping requirement that before its needs to be repaired in factory. Furthermore, in order to simplify the calculation process in model, this paper does not assign numerical values to R_i and R_{ij} . For this reason, those two parameters are equal to zero.

Table 4.Time consumption of shipping and berth before maintenance , sailing costs

	E11	E21	E12	E22	E13	E23
Time consumption of shipping and berth	4.5d	4.79d	5.08d	3.42d	5.81d	3.29d
Sailing time	3.5d	3.79d	4.08d	2.42d	4.81d	2.29d
Sailing costs	70 thy	75.8thy	81.6thy	48.4thy	96.2thy	45.8thy

Therefore, this study depends on the model and constraint conditions that an obvious result is given by table 5 as follows. Meanwhile, the figure 1 that include main influencing factors of scattered points are also given a nearly result.

Table 5.Total revenue of cargo shipping opportunity revenue subtract all costs

	E11	E21	E12	E22	E13	E23
Total revenue	381 thy	355.2thy	360.4thy	373.6thy	347.8thy	378.2thy

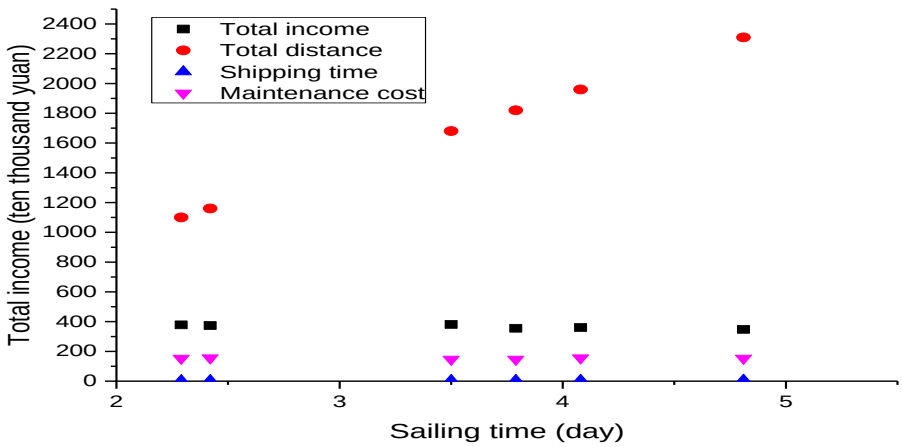

Figure 1. Influencing factors analysis of shipping opportunity

Conclusion

In accordance with above study results, the ship maintenance costs, sailing time, shipping distance and others are mainly attributed by influencing factors in operating revenue of ship when facing opportunity costs of maintenance and cargo shipping. In the light of assumed conditions, such as ship safety operating time, discount price of material supply in cargo shipping destination port and other smaller influencing factors are not considered in calculation of model. Therefore, when the berth costs per day, sailing costs per day and

unload and load time are fixed, the following factors of whole shipping distance, sailing time and maintenance time in factory and total maintenance costs have produce directly influences on total revenue. All in all, in the further study and actual application, this study gives some specific aspects for total revenue optimal and cargo shipping opportunity selection under ship safety operating time limit condition.

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