ISSN: 2688-8645

Optimization of Port Charges for Ship Berth Scheduling

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Abstract

With the continuous development of international trade, marine transportation plays an extremely important role in the current trade among countries.Ship cargo transportation has become an important logistics transportation mode because of its large transportation volume, high universality and low cost compared with other transportation modes.Good ship scheduling can reduce the waiting time of ships in and out of the port, and also reduce the cost of ships in the port.In recent years, with the proposal and wide application of various intelligent algorithms, the research on ship scheduling has achieved good results, but there are also some problems.Aiming at the ship scheduling problem, this paper establishes the objective function of minimizing the port charge, and uses genetic algorithm to simulate the ship for simulation experiments.The results show that the optimization of genetic algorithm can effectively reduce the in port cost of ships.However, there are more factors to be considered in practice, and the berth allocation model needs to be further optimized.

Keywords

Ship dispatching; In port expenses; Berth allocation; Genetic algorithm.

1. Preface

With the development of economy, maritime transportation has become the most important way of international cargo transportation. Its service quality is largely affected by the service efficiency of port ships. A scientific and reasonable port ship scheduling scheme can improve the service efficiency of ships and ensure the service quality of maritime transportation.On the other hand, the port plays a more and more important role in China's transportation industry and foreign development strategy. In this case, optimizing the ship scheduling scheme of the port can improve the service efficiency of the port, reduce the waiting time of ships entering and leaving the port, improve the service quality of ships, and greatly improve the competitiveness of the port in the general environment [1]. It can be seen that ship scheduling is not only an important part of port scheduling, but also the key work of port scheduling. Doing well in port ship scheduling is not only directly related to the profitability of the company, but also related to whether a port can effectively use resources and give full play to its potential.

For single channel ports, there will be ship detention, which greatly affects the ship service efficiency and ship service quality [2]. Therefore, the research on ship scheduling optimization can arrange more efficient scheduling schemes for ships, which has very important research and practical significance.

2. Introduction to Ship Dispatching

Ship dispatching refers to the daily work of shipping enterprises to organize and command the transportation and production of their ships in a planned way, timely grasp the navigation dynamics of ships and deal with relevant businesses during the operation of ships [3]. The work flow is as follows: (1) before normal work every morning, be responsible for contacting the Hong Kong side and recording the ship's entry and exit, operation balance, start /

completion time, etc. in the dispatching log. (2) In non holiday time, fill in the ship dynamic table of the current day according to the dispatching log.The contents of the dynamic table include the sailing time, completion time, loading / unloading or quantity of ships sailing within the first 24 hours, and the time to go to the port. The work on the first day after the holiday shall also include the ships sailing during the holidays;The arrival mission and arrival time of the ships expected to arrive in the next 24 hours;The operation progress of the operating ship on that day;Anchorage, ship, etc. (3) Copy the ship dynamic table and submit it to the Department Manager, who will distribute it to the relevant person in charge of the company.Dynamic tables can be in electronic form.

The research on port ship scheduling has made phased progress, but most of the existing research focuses on the integration and optimization of multiple resources [4], and there is little research on considering many details of ship scheduling for a specific port.The main optimization objective of port ship scheduling optimization problem is to improve the ship service quality of the port [5]. The decision points involved include the order of ships entering and leaving the port in the channel and the berthing position of ships in the berth, that is, the scheduling of ships and the allocation of ships in the berth respectively.Port ship scheduling optimization has always been a hot research issue in academic circles [6], and many scholars at home and abroad have studied its various aspects in detail.From the perspective of improving the service quality of port ships, it can be divided into research focusing on berth allocation, research focusing on channel ship scheduling and Research on coordinated scheduling of berth and channel resources [7].

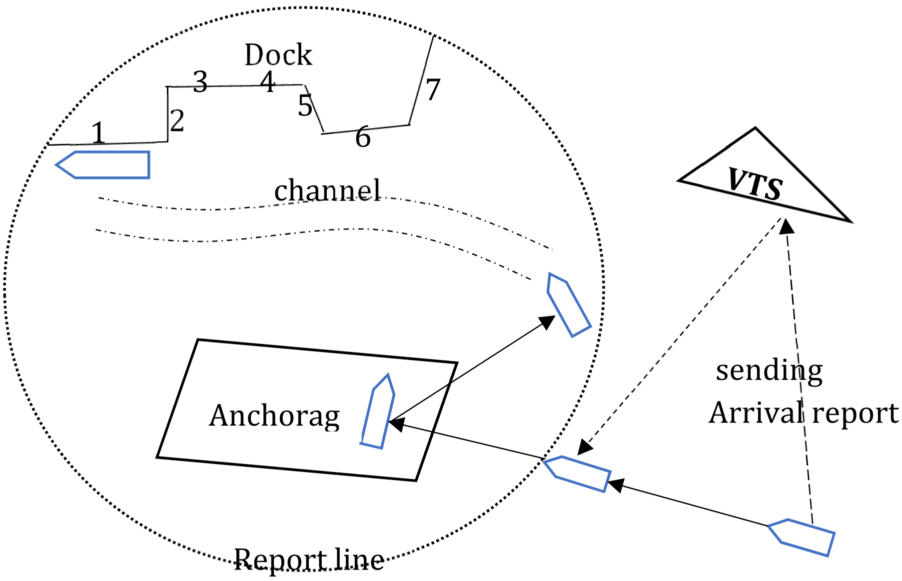

Figure 1. Simplified port ship scheduling model

3. Model Establishment

The ship scheduling problem in this paper is a ship scheduling problem based on one-way channel of port.Actual process of port dispatching: generally, incoming ships shall send the arrival and departure plan to the VTS center 24 hours in advance, and the arrival report shall be sent to the VTS center before the incoming ships arrive at the reporting line[8].Then VTS center will check its dispatching plan and arrangement. If the dispatching arrangement passes the review and meets the dispatching conditions, it will arrange the ship to enter the channel and berth;If it fails to pass the audit or there is no scheduling arrangement, it will generally be arranged to wait at the anchorage.The ship will arrange the agent to apply to the terminal enterprise for dispatching and apply to the pilot terminal for pilotage.The terminal enterprise arranges the dispatching and applies to the VTS center for review. After the review is passed, the ship will be notified, and the ship will complete the berthing and unberthing operation within the specified time [9]. After completing loading and unloading operations, the ship shall apply to VTS center for departure.If the conditions for departure are met, the ship shall leave the port with the assistance of tug and pilot;In case of conflict with other ships, the VTS center will generally let the ships wait at the wharf until they meet the conditions.After the ship leaves the reporting line, the entry and exit operations of the ship at the port are completed [10].

The purpose of this model is to improve the service efficiency of ships in the port, and to study the optimization of port ship scheduling based on one-way channel.

3.1. Model Assumptions

The assumptions of the model established in this paper include the following:

(1) The port has multiple anchorages with infinite capacity, and the influence of anchorage capacity on ship scheduling is ignored.

(2) The ship scheduling problem in a certain period of time is modeled.

(3) The water depth of the channel can meet the requirements of ships entering and leaving the port.

(4) This paper adopts the one-way navigation rule, that is, only the same direction navigation is allowed in the same time period

(5) When the ship applies for dispatching, the pilots, tugs and berths have been allocated and ready.

(6) Incoming ships wait for arrival at the anchorage and outgoing ships wait for departure at the berth.

3.2. Symbol Description

Symbol	explain
F	Indicates the completion time of all ships entering and leaving the port
tai	Time of application for dispatch of the ith ship
tsi	Time when the ith ship starts dispatching
d	Report the distance from the line to the channel entrance
fi	The end time of the i-th ship's arrival (departure)
vi	Average speed of the ith ship from entering the channel to arriving at the berth
wi	Waiting time of the ith vessel
IOi	The moving direction of the ith ship
Berthim	Status of berth m where the ith ship stops
Li	Master of the ith ship
Cl	Channel length
tgap0	Safe time interval to ship

3.3. Model Establishment

The core of the model is to reasonably arrange the ship in and out of the channel according to the ship arrival order, reduce the in and out conversion time of the one-way channel, and enable as many ships to complete the port operation plan in a short time on the premise of ensuring safety. [11]

The objective function of the scheduling model in this paper is:

$$minimize \sum_{i=1}^{N}(t_{si} - t_{ai}) \tag{1}$$

The constraints are as follows:

$$t_{gap0(i)} = 6 * \frac{l_i}{v_i} \quad (2)$$

$$t_{gap1(i)} = 6 * \frac{\max(l_i, l_j)}{v_i} \quad (3)$$

$$t_{si} \geq t_{ai} + IO_i * (1 - k_{im}) * M \quad (4)$$

$$t_{c1i} = t_{si} + IO_i * \frac{d_i}{v_i} + (1 - IO_i) * \frac{s_i}{v_i} \quad (5)$$

$$t_{c2i} = t_{c1i} + \frac{cl}{v_i} \quad (4)$$

$$\begin{cases} t_{c1i} \geq t_{c1i} + t_{gap0} \\ v_i \leq v_j \end{cases} \quad (7)$$

$$t_{c1i} \geq t_{c2i} + t_{gap1} \quad (8)$$

$$t_{si} + \frac{(DB_i - DB_j)}{v_i} \geq t_{c2j} + \frac{s_j}{v_j} + t_{gap1} \quad (9)$$

$$t_{si} \geq t_{2cj} + \frac{DB_i}{v_j} + t_{gap1} \quad (10)$$

The objective function is a ship scheduling optimization model established for the purpose of minimizing the total waiting time of ship scheduling.

Equation (2) represents the minimum chase time interval when ship I and ship J travel in the same direction (the time is equal to the length of ship I divided by the s distance of 6 times the speed of ship I).

Equation (3) represents the minimum encounter time interval when ship I and ship J travel in the opposite direction (the time is equal to 6 times the length of ship I and ship J divided by the speed of ship I).

Constraint (4) ensure that each ship must arrange time after application. If the ship enters the port, there must be available berths.

Equation (5) shows that the time when ship I enters the channel is equal to the time when ship I starts planning plus the time when the ship enters the channel from the current position;If the ship I enters the port, its distance is di;Otherwise, the driving distance is si.

Equation (6) shows that the time when the ship I leaves the channel is equal to the time when the ship I approaches the channel plus the time when the ship passes through the channel.

The constraint (7) ensures that the time interval between vessel I approaching the channel and vessel J approaching the channel is at least tgap0 (I) (if they travel in the same direction);In addition, the speed of ship I shall not exceed the speed of ship J.

Constraint (8) ensures that the time interval between vessel I approaching the fairway and vessel J leaving the fairway is at least tgap1 (I) (if vessel I enters the port and vessel J travels in the opposite direction).

Constraint (9) ensures that the time interval between the arrival of vessel I at the berth of serving vessel J and the arrival of vessel J at its berth must be at least tgap1 (I), provided that vessel I is leaving the port and vessel J is moving in the opposite direction, and the berth of serving vessel I is farther than that of serving vessel J.

Constraint (10) ensures that the time interval between the start schedule of ship I and the arrival of ship J at the berth that ship I will serve is at least tgap1 (I), provided that ship I leaves the port, ship J is driving in the opposite direction, and the berth that ship I will serve is closer than the berth of ship J.

4. Algorithm Design and Results

4.1. Algorithm Design

In this paper, genetic algorithm is used to solve the ship scheduling problem in one-way channel [12]. Annealing mechanism is added on the basis of genetic algorithm, which makes the algorithm structure better, speeds up the convergence speed and avoids falling into local optimization.The steps of genetic algorithm are:

Step 1: initialize parameters, adjust population size and total number of ships;

Step 2: if there is no corresponding berth, set the first period as the arrival time and go to step 5, otherwise go to step 3;

Step 3: if all ships are corresponding ships from corresponding berths, set the first period as the departure time and go to step 5, otherwise go to step 4.

Step 4: randomize the port types in and out of the first cycle;

Step 5: if this is the arrival time, determine the number and arrival order of incoming ships in combination with the arrival time of ships, and arrange the arrival of each port and ship and update the departure time;Otherwise, go to step 6;

Table 1. Dispatching ship information

Number	ETA	Operation time	DWT	cost
1	0	25	41392	0.27
2	5.5	23.5	66557	0.43
3	16.5	20.5	67500	0.44
4	17.5	21	51335	0.33
5	18.7	42.8	70851	0.46
6	18	11.5	32706	0.21
7	23.5	23.2	69411	0.45
8	25.5	20	59850	0.39
9	38	13	18533	0.18
10	44	13.8	37248	0.24
11	50.3	25	68704	0.28
12	53	23.7	43546	0.33
13	62.3	24	97200	0.37
14	64	24	42940	0.41
15	71	24.7	68342	0.45
16	72.5	70	92160	0.49
17	73.5	34.3	82800	0.53
18	78.3	19	67840	0.58
19	80	22.5	41819	0.62
20	82	20	55832	0.55

Step 6: determine the number and sequence of departure ships after the departure time of each port area, organize departure and update the arrival time of ships;

Step 7: if the number of ships entering and leaving the port is less than the total number of ships, it shall be updated alternately at intervals and rotated to the fifth or eighth stage;

Step 8: if the ship is smaller than a certain scale, then step 2, otherwise it ends.

4.2. Experimental Result

Now, it is assumed that there are 7 berths in the port. Now, the ships are scheduled according to the collected arrival information of some ships. The collected scheduling ship information is shown in Table 1 below.

If not optimized by genetic algorithm, the berth scheduling scheme in the initial ship population is shown in Table 2 below.

Table 2. Initial berth scheduling scheme

Berth 1	Berth 2	Berth 3	Berth 4	Berth 5	Berth 6	Berth 7
9, 16, 3, 15	1	19	5,7,14, 18,17,4	20,11,8, 12,13,6,2	10	

The berth scheduling scheme of the optimal solution optimized by genetic algorithm is shown in Table 3 below.

Table 3. Optimized berth scheduling scheme

Berth 1	Berth 2	Berth 3	Berth 4	Berth 5	Berth 6	Berth 7
2,7,12,20	3,14	1,9,10,15	4,11,18	5,13,16	6,17	8,19

From the above, after genetic algorithm optimization, the port fee has been greatly optimized, and the utilization rate of berths has also been improved.However, the mathematical model is obtained on the basis of certain simplification. Even if it has a certain reference and auxiliary decision-making function for the actual port berth allocation, there are still many places to be improved in terms of the actual situation of the port.

5. Existing Problems and Innovation Direction

5.1. Existing Problems

At present, a lot of research on ship scheduling has been carried out at home and abroad.Although there are many methods of ship scheduling algorithm, it still faces many difficulties, mainly because the ship port scheduling problem is a design multi department[13] and multi role problem. The scheduling problem itself is very complex, which is difficult to completely recover in the modeling process and can only be simplified.

1) When modeling the ship scheduling problem, generally only the port ship scheduling optimization problem under normal conditions is considered, and no further research is done under abnormal conditions.

2) For the establishment of port models, most of them are briefly modeled in the ideal state, and do not show the actual situation of the port.

3) Most of them only consider conventional ships, and do not accurately consider the ships with limited draft.

ISSN: 2688-8645

5.2. Innovation Direction

Based on the analysis of the above problems, the following suggestions are put forward for the development of Ship Scheduling Optimization:

1) When modeling the ship scheduling problem, the weather anomaly and ship anomaly can be considered [14], and the constraint conditions can be established;

2) For port modeling, we should select the real port as a reference and improve the details of the port model;

3) Special consideration shall be given to special ships such as draft Limited ships;

6. Summary

With the continuous development of science and technology, the environment faced by ship scheduling algorithm will be more and more complex. The algorithm used in ship scheduling must have the ability to quickly respond to the changes of complex environment.Using one or a class of algorithms alone often can no longer solve the complex problems encountered in ship scheduling due to its own limitations[15].The combination of multiple algorithms to improve the performance of algorithms is the main direction of algorithm research.The optimization of ship scheduling algorithm is the main direction of ship scheduling problem.

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