Study on Disruption Management Models of Continuous Berth Allocation at Shipyard Jetties

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Abstract **- On adjusted plans of berth allocation at shipyard jetties caused by disruptive events, solutions are given based on concepts of disruption management. Also system disruptions are measured on position and time costs of berth deviation, and disruption management models are built. Finally, multi-objective genetic algorithm is used for problem solving, in an effort to obtain new distribution plans. Experimental samples show that compared with rescheduling, disruption management solutions see a lower plan restoring cost of ships. And the disruption management model considers benefits from many aspects, resulting in more scientific solutions.**

Keywords - Berth scheduling, shipyard, uncertain factors, disruption management, multi-objective genetic algorithm

I. INTRODUCTION

The shipyards, especially the ship repair yards, involve a great quantity of operations of the vessels to shift berths at the port terminal. Scientifically arranged mooring points and optimized shifting operation sequence of multiple vessels are very important for a maximum use of the production resources of the shipyard.

However, as the external environment is always in dynamic, active and complicated changes during the practical operating process of ship repairing, the occurrence of uncertain events is inevitable and often unforeseen, and thus causing more or less interference on schedules made in advance. These interference events may disrupt the original schedule of berth allocation and make it infeasible. Therefore, adjustment to the original schedules and minimizing the negative impacts of interference events on the system constitute the main problems studied in the context of disruption management in berth allocation. At the present stage, for there have been few theoretical researches on this aspect, methods based on human's experience and re-scheduling are commonly used in the production practice. The former has the advantages of simple practice and fast response, but its ultimate effects often depend on the experience and responsibility of the coordinators, with great uncertainty; while the latter, which performs global re-optimization and re-adjustment to the system based on the state after interference event, can achieve the original optimization goals, but may significantly disrupt the system, and thus making the new plan infeasible.

There have been a few researches on disruption management in the context of berth allocation at the port terminal. However, due to the development and prosperity of the world's shipping industry in recent years, domestic and overseas scholars mainly focused on the transporting arrangement of the shipping and vessels and cargoes (especially container) in port and few involved in this field of berth shifting in shipyards, according to the current literature.

In terms of its production features, berth allocation at terminals in ship repair yards consists of a series of organized and scheduled operating activities of vessels, influencing and restricting each other. Abnormal operation of one vessel often leads to change in schedule and interference to normal production operations of other vessels, resulting in some certain economic loss for the enterprise. This paper attempts to introduce the theory of disruption management into berth allocation at terminals in ship repair yard and propose to decision-making methods of disruption management, including classification of interference events and quick access to reasonable scheduling scheme, to provide effective means of production management for the terminals of ship repair yards.

II. PROBLEM DESCRIPTION AND DECISION METHOD

Berth dispatching system comprises of discrete and continuous arrangement according to the actual berth arrangement method at dockyard. Continuous berth positions can be abstracted as: Find an area for each ship, to satisfy demands of ship length and operations. The occupancy of berth resources by each vessel is reflected by the rectangular area in the coordinates. As shown in Fig. 1.

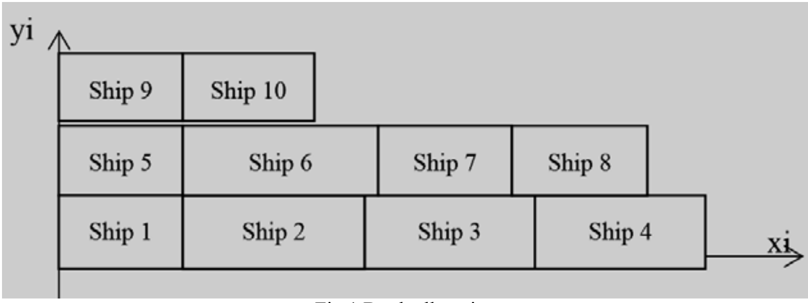

Fig.1 Berth allocation

(xi,yi) shows the position of vessels i. i ∈S, S is the set of all vessels. S ={1,2,3,…,s}.

Two typical classes of interference with great impact on berth scheduling at terminals of shipyards:

Changs in terminal environment and personnel, time deviation of scheme implementation, status of equipments and vessels, etc.;

Scheduled delays and cancellations of berthing of vessels, unscheduled emergency operations of vessels, etc.

These uncertainties will generally cause more or less interference on the scheduling plans of the berths.

Superficially, the simplest approach is to optimize the scheduling plans and develop a new comprehensive implementation scheme in light of the occurred uncertainties. However, this processing method of scheduling and re-scheduling generally causes a great disturbance to the system, probably resulting in an infeasible new scheme.

For this reason, a better solution dealing with this problem is to adjust on the basis of the original schedule and to minimize the magnitude of change in the original schedule, trying to keep the continuity and integrity of the system. On the basis of this idea, the decision goal of disruption management in berth scheduling at terminals can be determined as follows: To minimize disturbance on the implementation of original schedule through local adjustment to the scheme, i.e. to obtain a satisfactory alternative scheme with minimum cost.

Figure 2 (a) shows the initial scheduling plan of 5 vessels in dynamic continuous berths, with the horizontal axis representing frontage, the vertical axis representing time, and the rectangular box representing berthing scheme. Figure 2 (b) shows 3 common interference events (represented by the dashed box) of vessels during the implementation of scheduling plan: scheduled berthing cancellation of vessel A and berthing delay of vessel B and unscheduled emergency operations of vessel F. In this case, following problems need to be solved: (1) For berthing schemes of vessels B and E are overlapped, both of their original scheduling plans have been infeasible; (2) a suitable space should be found to arrange vessel F; (3) berthing schemes of vessels C and D should be ensured unaffected as much as possible. The main direct solutions to the above problems: Delay the berthing time of E, change the berth of B, and arrange F in an unoccupied berth. The various solutions above are also the experience methods commonly used in manual operations and can achieve satisfactory effects when the port terminal is small and few vessels are disturbed. However, when the scale of the problem and degree of disturbance have further increased, selection of appropriate methods should be taken into consideration to minimize disturbance to the system and quickly obtain a reasonable scheduling scheme, which is the main content of research on approaches of disruption management.

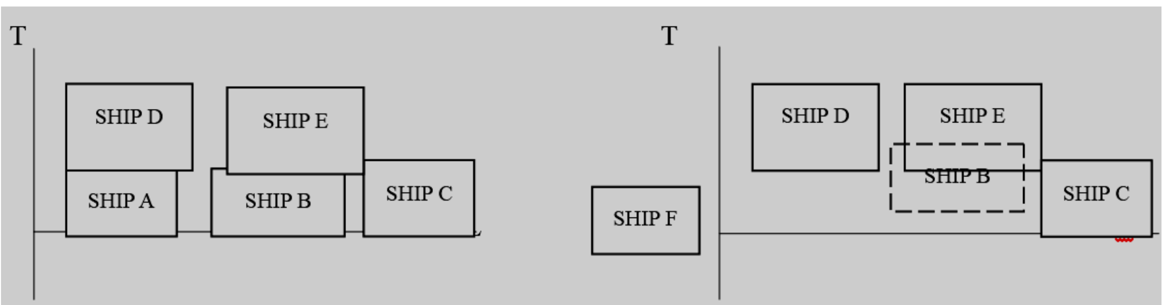

Fig.2 Disturbance characteristics of vessels under continuous berths.

III. DISTURBANCE RECOVERY MODEL

A. Relevant Parameter

S1: the set of vessels delay or cancel enter shipyard, S1 = {1, 2, 3,…,s1};
S2: the set of vessels unplanned enter shipyard, S2 = {1, 2, 3,…,s2};
S0: the set of vessels to be disturbed, S0 = {1, 2, 3,…,s0}; S0=S1+S2;
L: the length of the wharf (m);
li: the length of vessel i (m) (Including the safe distance), i∈S0;
bi: the plan berthing position of vessel i, i∈S1;
ti: the plan berthing time of vessel i, i∈S1;
Bi: decision variable, the actual berthing position of vessel i, i∈S0;
Ti: decision variable, the actual berthing time of vessel i, i∈S0;
Tai: the estimated arrival time of vessel i, i∈S0;
Tbi: the estimated unberthing time of vessel i, i∈S0;
zij: dependent variable, if vessel i is berthed on the left of vessel j on the wharf, zij=1, otherwise zij=0,
i, j∈S0;
θij: dependent variable, if vessel i s berthed before vessel j in time, θij=1, otherwise θij=0, i, j∈S0;
c1: the penalty cost of vessels not berthed position in plan;
c2: the penalty cost of vessels delay enter shipyard;
Xi: the working condition of vessel i on the berth, Xi=1, show that vessel i is operated on the berth, otherwise Xi=0, i∈S0;
M: A large constant.

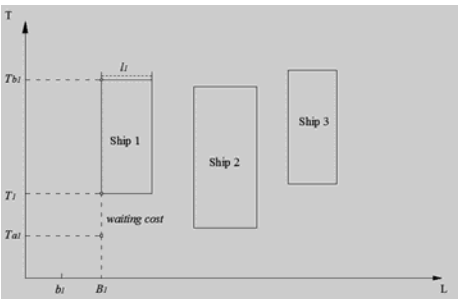

Fig.3 Relevant parameter

B. Mathematical Model

Then, the objective function of disruption management model of the ship berthing problem can be written as follows:

$$f_1 = \min c_1 \sum_{i \in s_1} \left| B_i - b_i \right|, \tag{1}$$

$$f_2 = \min c_2 \sum_{i \in s_1} \left| T_i - t_i \right|, \tag{2}$$

$$f_3 = \min \sum_{i \in s_2} \left| T_i - T_{ai} \right|, \tag{3}$$

Subject to

Ti≥Tai   ∀ i∈S0, (4)
Bi≥0∀i∈S0, (5)
Bi+li≤Li∀i∈S0, (6)
Bi+ li ≤ Bj+ M(1- zij) ∀i,j∈S0 i≠j, (7)
Tbi≤Tj+ M（1-θij), (8)
zij+zji+θij+θji≥1   ∀i,j∈S0   i≠j, (9)
zij ,θij∈{0,1}   ∀i,j∈S0   i≠j, (10)

Eqs. (1) - (2) imply position and time costs of berth deviation. Eq.(3) implies that unscheduled vessels berthing waiting time are shortest. Eq. (4) implies that a vessel cannot berth before she arrived; Eq. (5) implies berthing position must Greater than zero. Eq. (6) implies that the position of vessel i is restricted by the length of the wharf; Eqs. (7)—(8) imply the relationship of berthing position and time between two vessels; Eq. (9) implies the schedules for vessel i and j can’t overlap. Eq. (10) defines the two dependent variables zij, θij.

IV. SOLUTION PROCEDURE

For multi-objective problem models on a large scale, the accurate algorithm is hard to calculate a feasible solution within limited scope of space. The successive berth allocation system is similar to “knapsack” problem, so that we introduce the representative result NSGAⅡin multi-objective optimization algorithm, depending on the idea of solving problems thereof. The following are steps:

(1) Initialization

Now that an optimization model had two decision variables, individuals in this paper could be represented by chromosome complements and each daughter chromosome was coded with a natural number. For the generation of initial population, a random generation method was adopted to ensure the diversity of population and avoid non-feasible solution in the process of population evolution. For example, the gene position of daughter chromosome #1 which had a coding scheme based on priority, stood for ship No. and its gene value represented ship service sequence; while the gene position of daughter chromosome #2 also denoted ship No., its gene value signified the ship’s berthing position and was generated randomly within the range of [0, L] as shown in Table 1.

TABLE 1 EXPRESSION OF CHROMOSOME GENE

Ship No.	1	2	3	4	5	…
daughter chromosome 1	1	3	4	5	2	…
daughter chromosome 2	T1	T2	T3	T4	T5	…

(2) Fitness function

It was computed in accordance with the objective function.

(3) Crossover mutation

As encoding was carried out by seeing chromosome complement forms as individuals in this paper, a Two-point Crossover method was employed in the first place to perform crossover operations. In case that filial generation obtained after crossover was infeasible, that is, it did not meet constraint conditions, a switching strategy and an adjustment strategy were necessarily used to make the filial generation satisfy these constraints and thus become a feasible solution. When it came to mutation operation, chromosome #1 and #2 respectively adopted the exchange mutation and random real value variation methods.

(4) Pareto grading

The following are steps:

① Set the initial sequence numbers, and make grad=1;

② Randomly select a solution X* from Pop(G), the G generation of the population, as the reference solution, and compare it with all the other solutions in the population, if X* dominates all the other solutions, make the grade of it—grade(X*)=grad. Repeat this process until all the other solutions have been selected as reference solutions.

③ Remove all the individuals with the grade of 'grad' from the population;

④ If there still exit the individual whose grade is not determined in the population, make grad=grad+1. Jump to ②, until all the individuals in the population have been processed.

(5) Crowding distance calculation

As far as crowding distance calculation was concerned, all individuals in a population should be sorted in ascending order in line with each corresponding objective function. The corresponding two individuals of the maximal and minimal values were set to have an infinite crowding distance. Then the crowding distance of individual #i could be set as the sum of all objective function values' differences obtained from individual #i+1 and #i.

(6) Selection process

According to Pareto classification and crowding distance, N individuals were selected from 2N ones as the next generation. Firstly, all individuals were sorted in ascending order in terms of their controlled levels; secondly, individuals with the same controlled level were then sorted in descending order according to their crowding distance; and finally, the first N individuals were chosen from such a sequence to be the next generation population.

(7) Termination condition judgment

If the evolution algebra was regarded as a condition for estimation termination, when this algebra is smaller than the set value, we needed to return to Step (4); otherwise, results would be exported.

V. ANALYSIS OF EXAMPLE

The actual statistical data form a shipyard in southern China, L=1000 m, l=rank（100,300m）, c1=l0rmb/10m; c2=1400rmb/h. In a production cycle, using the ship berthing time for the minimizing target, Eq. 5~11 as constraint conditions, using the genetic algorithm to get beginning berthing schedules and location, when there are 10 vessels in the shipyard (S=10).

As shown in Fig.4, (xi,yi) shows the position of vessels i. i∈S. For the different ship in the same berth, the relations of the ship berthing location and time as shown in implementing line rectangle in Fig.5. the abscissa as dL (d1 is the berthing,d2 is the double berthing), y coordinate for the cycle time (days).

When T=0, quay dispatcher know in advance that ship 2, 3 will be postponed to shipyard, delay time is respectively 2 and 4 days; ship 4 will be cancelled to come to shipyard. Other plan ship 11 to be come to shipyard after 7 days. Due to the influence with this three cases, ship 2 and ship 7 in the same berth, but different row, which will affect the ship 7 berthing, the delay berth of ship 3 will affect the ship 10 berthing plan, the beginning berthing schedules has become unavailability, and to be adjusted.

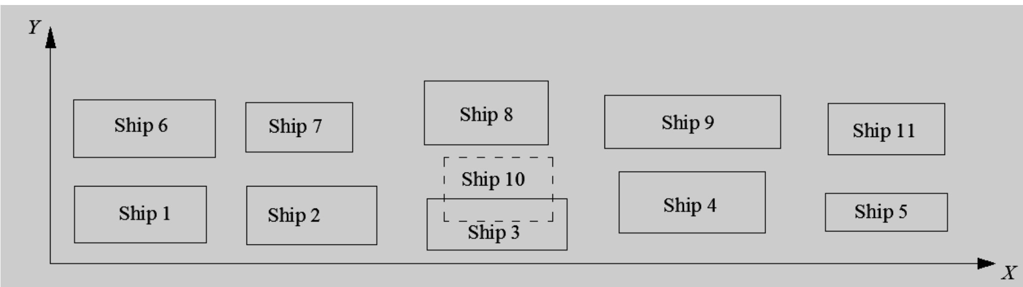

Fig.4 Berth allocation

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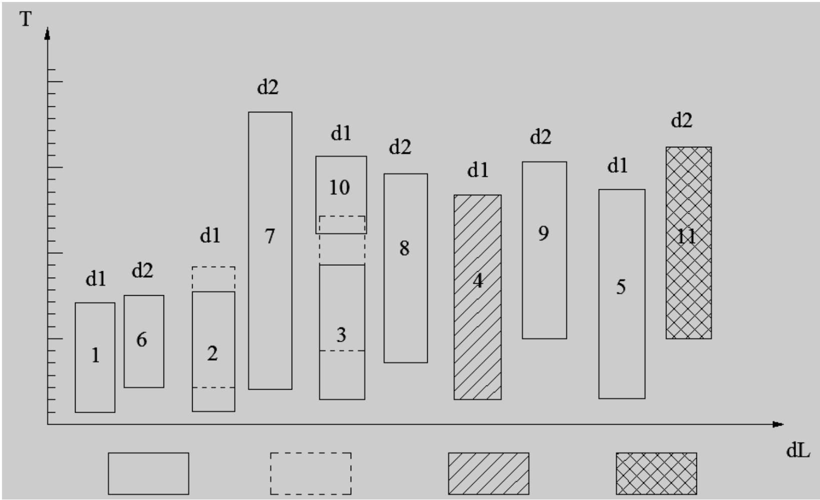

Fig.5 2-Dimensional Berth-Time Plane

Use matlab2010a for algorithm programming. By comparison, adopt rescheduling for problem solving of the sample. Take the optimal objective as the original one, and minimize the berth time of ships.

TABLE 2 SCHEDULING RESULTS CONTRAST

Project	plan-restoring cost of ships/rmb
Disruption Management	206640
Rescheduling	306432
The degree of disruption management optimization	48.3%

Compared with rescheduling methods, solutions based on optimized disruption management greatly contribute to reducing ship restoring costs, enabling terminal operations to restore to normal production orders with minor disruptions.

VI. CONCLUSION

The article investigates disruption management methods of continuous berth allocation of shipyard jetties, which covers the whole process from disrupting berth allocations to generating new plans, with its validity verified by examples. It concludes that by classifying those disruption events during operations it is possible for the restoring strategies to work more specifically, responding faster and making decisions quickly. During the restoring optimization, optimized models take accounts of planning restoring costs of ships (penalty costs), minimizing unexpected berthing time, resulting in minimizing system disruptions, in line with decision-making demands of disturbance management. Therefore disturbance management methods for restoring ship plans are preferable to those of rescheduling, with multi-objective genetic algorithms contributing to optimal solutions in a timely way.

In fact, disturbance management is in a dynamic process. Any dynamic and online optimization of the method will be studied further.

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