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Cost Optimization of Inter-terminal Container Transportation

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Abstract

This paper studies the cost optimization problem of inter-terminal container transshipment. Based on the multi-terminal container transshipment business, it considers how containers are allocated to container trucks and how containers are transported by collecting cards, and minimizes the total cost of inter-terminal container transshipment.In order to achieve this goal, this paper establishes a nonlinear mathematical distribution model for inter-terminal container transfer costs.The decision variables with 0-1 logical constraints were used to determine whether containers were allocated to set cards, the order of container transport with set cards and the number of containers allocated.The constraint condition of big M method is used to determine whether the set card is to transport a single container or two containers in a package.In order to verify the effectiveness and feasibility of the model and algorithm, this paper takes Yangshan Phase 2 and Phase 3 container terminals of Shanghai Port as an example to model and solve the inter-terminal container transshipment cost, and obtains reasonable container transshipment cost results through the improved genetic algorithm.

Keywords

Inter-terminal container transfer cost; Set card allocation; Container transport; Genetic algorithm.

1. Introduction

1.1. Research Background

Since the advent of container transport, with its unique transport advantages, quickly occupied the sea transport.Container transport is a kind of logistics transport mode that combines railway transport with waterway transport.It passes the transport mode of simple consign, charge, a piece of paper and insurance by the carrier of different transport section undertakes to complete the social economy activity that is the purpose with goods transport jointly.According to statistics, ship transport accounts for 90% of the world's international cargo transport, of which container transport accounts for 80%. Since the new century, with the deepening of economic globalization and integration, the trade volume between countries has shown a step-type growth, which promotes the rapid development of container transport industry, and the container transport mode is favored by people.Correspondingly, on the basis of the expansion of the container transport industry, the specialized container terminals have been gradually separated and gradually evolved into an important link in the container transport network.

The inter-container terminal truckage business is a cargo transportation operation in which vehicles are allocated in the same port, and then the vehicles transfer the containers from one terminal to another.There are two main reasons for such transportation: first, because the container is delayed in the process of transportation, so it is forced to transfer, so the vehicle is assigned to transfer the delayed container to the designated terminal;Second, ships in port when loading, usually will appear to be of the same ship container to be stored in the same port of different terminals, port operators and shipping companies from raising the loading efficiency, cost savings and shorten the waiting time of ships in the port of factors to consider, will arrange vehicles in advance, for shipment to container transport to the same terminal[1].

In this paper, the vehicle transfer container business between container terminals is similar to the vehicle towing business between container terminals.Vehicle towing service is a specific form of cooperation between adjacent docks. The docks are connected with each other by means of towing channels, so that containers can be loaded and unloaded in adjacent docks. At present, there are few studies on this issue by domestic and foreign scholars.However, this method has already been used in many container ports such as Shanghai Haiyangshan Port Area and Waigaoqiao Port Area.

1.2. Research Status at Home and Abroad

In recent years, container transport at home and abroad is in a period of rapid development, and various port terminal operators are also in full steam to expand the number of berths and their draft depth, but there are also different types and forms of operation. At present, the research directions of inter-terminal container transport mainly focus on cost control of container terminal, optimization of multi-equipment integrated scheduling and inter-terminal optimization. This paper will focus on the research of inter-terminal container transshipment costs and how to allocate vehicle transshipment containers.

1.2.1 Research on inter-terminal problem

Due to the continuous growth of container transport, port development is limited to some extent.In order to improve the competitiveness and handling efficiency of ports, scholars at home and abroad begin to pay attention to the optimization of interport transportation.Inter-terminal transportation (ITT) refers to the transportation of containers between terminals. It is not only a problem for port authorities and terminal operators, but also a strategic issue to be considered when planning new terminals and container ports.

In 2018, Qu Hu et al[2] studied the mathematical model of container transport planning based on inter-terminal network, which combined inter-terminal transport in port area with railway transport to hinterland, and comprehensively planned the transport network connecting railway and hinterland.The tabu search algorithm and spatiotemporal network distribution diagram can be used to solve the large-scale container transportation problem between terminals.

Xue Song[3] studied the integrated scheduling problem of berths and quay Bridges under the coordination of multiple docks, and minimized the production and operation costs of docks based on the difference of tide and berth water depth.By designing a hybrid heuristic algorithm to solve a large scale example, the advantages of multi-terminal integrated scheduling are highlighted.

1.2.2 Research on the cost of container transshipment

In order to reduce the operation cost of wharf and maximize the benefit, the research on wharf cost control has always been a hot topic for wharf operators and experts.

Massimo Di Francesco et al[4] analyzed the short-term labor cost of container transit terminals.The integer linear mathematical model is constructed and compared with the actual human decision-making. The results show that the model can obtain the optimal solution in small, medium and large transit container terminals.Ziaul Haque Munim and Hercules Haralambides[5] analyzed the competition and cooperation between ports in Bangladesh and India, and obtained the optimal economic benefits between ports in the mixed integer programming model.After calculating the reduction of transshipment costs, port operators can reap great benefits.

2. Modeling of Inter-Terminal Container Transportation Cost

2.1. The Research Content

As can be seen from the above review analysis, the research on container terminal transportation and transportation cost reduction has attracted extensive attention from scholars at home and abroad, but there are few researches on the optimization problem of inter-terminal container transfer cost based on vehicle allocation.The research contents of this paper mainly include the following parts:

(1) Take the Phase 2 and Phase 3 container terminals of the above harbors in Yangshan Port Area as an example. Each transshipment container is regarded as a transportation task. A transportation task can transport a single 20ft container or pack two 20ft containers.

(2) Optimize the inter-terminal container transfer cost based on the consideration of vehicle allocation, vehicle packaged transport or separate transport container and vehicle transport container sequence.

(3) A mathematical model of container terminal transport cost with vehicle allocation is constructed, and the advantages of transport cost of this model are highlighted by combining separate cloud and packaged transport.The results show that the vehicle distribution scheme is also consistent with the actual situation, which provides a theoretical basis for the port vehicle transport container business.

2.2. Network Node Diagram

In order to describe this problem in more detail, this paper analyzes and studies the towing business between docks from a more detailed perspective.Due to the neat and uniform layout of container terminals, the container transfer node diagram is drawn by marking the container location number in the field with Arabic numerals, as shown in Figure 1.After using Google earth software to measure the actual distance, the length and width of the box area can be set as 500m and 300m respectively in this example.In order to quantify the starting point of container transfer and facilitate mathematical calculation, the width is divided into five equal parts.We assume that the stage in yangshan port 2 and 3 port, any there are eight columns box the container transport demand, the margin between two terminals as a channel, each span is 100 m, 8 nodes and node 48, considered to be the starting point for the transshipment containers, and the starting point can be randomly generated by matlab 1 to 30 and 31 to 60 positive integer to represent.

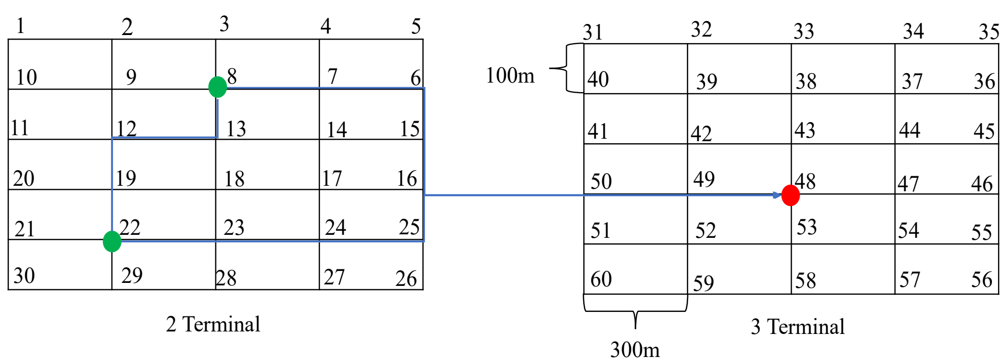

Figure 1. Container transport node diagram.

2.3. Mathematical Model

In this paper, the model is used from the integer linear programming model established by Zhihua Hu.

2.3.1 The parameters in this model are as follows.

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I—— A set of tasks indexed by i, j, l
I^o—— A set of task initial nodes
I^F—— A set of task set destination nodes
V—— A set of vehicles
N—— A set of vehicle transport task sequences
i, j—— Transportation task i, j
M—— Very large numbers
K—— number of vehicles
S—— Speed of vehicle
C—— Unit distance transport cost of container
$U_{i,k}$— Elimination subloop

2.3.2 Variables

$x_{i,j,k}$ Whether vehicle k carries tasks i, j continuously

$x_{i,k}$ Whether task i is assigned to vehicle k

$y_{i,k,n}$ Whether task i is transported by vehicle k for the NTH time

d_{ij}^{one} The distance to be transported when task i is transported alone

d_{ij}^{double} The transport distance of tasks i and j when they are packaged and transported

2.3.3 Objectives

$$\min Z = \sum_{i,j,i\neq j}(d_{ij}^{one} + d_{ij}^{double}) \cdot C \tag{1}$$

In the model, Formula (1) represents the objective function of the model, and $d_{ij}^{one} + d_{ij}^{double}$ is the transport distance between transporting a single container and transporting two containers in a package

2.3.4 Constraint

$$\sum_{i\in I^F} \sum_{k\in K} x_{Oik} = |K| \tag{2}$$

$$\sum_{i\in I^o} \sum_{k\in K} x_{iFk} = |K| \tag{3}$$

$$\sum_{j\in I^F} x_{ijk} = \sum_{j\in I^o} x_{jik} = x_{ik}, \ \forall i \in I, k \in K \tag{4}$$

$$\sum_{k\in K} x_{ik} = 1, \ \forall i \in I \tag{5}$$

$$U_{j,k} = U_{ik} + 1 + \left(x_{ijk} - 1\right) \cdot M, \ \forall (i,j) \in I^2, i \neq j, k \in K \tag{6}$$

$$\sum_{n\in N} y_{i,j,k,n} \leq x_{ijk}, \quad \forall (i,j) \in I^2, i \neq j, k \in K \tag{7}$$

$$\sum_{n\in N} y_{i,k,n} \leq x_{ik}, \quad \forall i \in I, k \in K \tag{8}$$

$$\sum_{n\in N} y_{i,k,n} \leq 2, \quad \forall n \in N, k \in K \tag{9}$$

$$y_{i,j,k,n} = y_{i,k,n} \cdot y_{j,k,n}, \ \forall (i,j) \in I^2, i \neq j, k \in K, n \in N \quad (10)$$

$$d_{ij}^{one} \geq \sum_{k \in K} x_{ijk} \cdot [L(O_i, D_i) + L(D_i, O_j)] - \sum_{k \in K} y_{ijkn} \cdot M_1, \forall (i,j) \in I^2 \quad (11)$$

$$d_{ij}^{double} \geq L(O_i, O_j) + \sum_{l \in I, k \in K} [L(O_j, D_i, D_j) + L(D_i, D_j, O_l)] \cdot x_{jlk} + (\sum_{k \in K, n \in N} y_{ijkn} - 1) \cdot M_2, \ \forall (i,j) \in I^2 \quad (12)$$

$$x_{i,j,k} \in \{0,1\}, \qquad \forall (i,j) \in I^2, k \in K \quad (13)$$

$$x_{i,k} \in \{0,1\}, \qquad \forall k \in K \quad (14)$$

$$y_{i,k,n} \in \{0,1\}, \qquad \forall n \in N \quad (15)$$

$$y_{i,j,k,n} \in \{0,1\} \quad (16)$$

$$d_{ij}^{one} \geq 0, \qquad \forall (i,j) \in I^2 \quad (17)$$

$$d_{ij}^{double} \geq 0, \ \forall (i,j) \in I^2 \quad (18)$$

2.4. Improved Particle Swarm Optimization Algorithm

In this paper, the improved genetic algorithm is based on a set of feasible set card allocation number to encode, and then complete the preprocessing, and ensure the set card allocation and container transport number constraints.These codes will finally find the optimal allocation scheme of set card through a series of iterations. Iterations mainly include three basic genetic operators, namely selection, crossover and mutation, which are similar to genetic laws in biology.At the end of each iteration, the fitness function should be used for fitness evaluation, and the coding of the next iteration should be selected according to the fitness index.The probability of crossover and mutation in each iteration can be set, and the different setting of the numerical value will have a certain impact on the calculation result. The crossover and mutation realize the change of coding.This process is repeated until the number of iterations is satisfied and the iteration is terminated.

2.5. Data and Solution

Table 1. Shows the O-D distance of the calculation example

task		1	2	3	4	5	6	7	8	9	10
	node	22	13	15	29	13	11	26	27	24	12
1	47	2000	1700	1100	2100	1700	2300	1200	1500	1400	2000
2	48	1700	1400	800	1800	1400	2000	900	1200	1100	1700
3	39	1600	1100	500	1700	1100	1700	800	1100	1000	1400
4	60	1100	1000	400	1000	1000	1600	100	400	500	1300
5	33	2000	1500	900	2100	1500	2100	1200	1500	1400	1800
6	49	1400	1100	500	1500	1100	1700	600	900	800	1400
7	35	2600	2100	1500	2700	2100	2700	1800	2100	2000	2400
8	54	1900	1800	1200	2000	1800	2400	1100	1400	1300	2100
9	35	2600	2100	1500	2700	2100	2700	1800	2100	2000	2400
10	58	1700	1600	1000	1600	1600	2200	700	1000	1100	1900

2.5.1 Data

Because it is difficult to obtain real data, the randomly generated data is adopted as the basis of calculation, and the initial data is generated mainly by using MATLAB software.

2.5.2 Solution

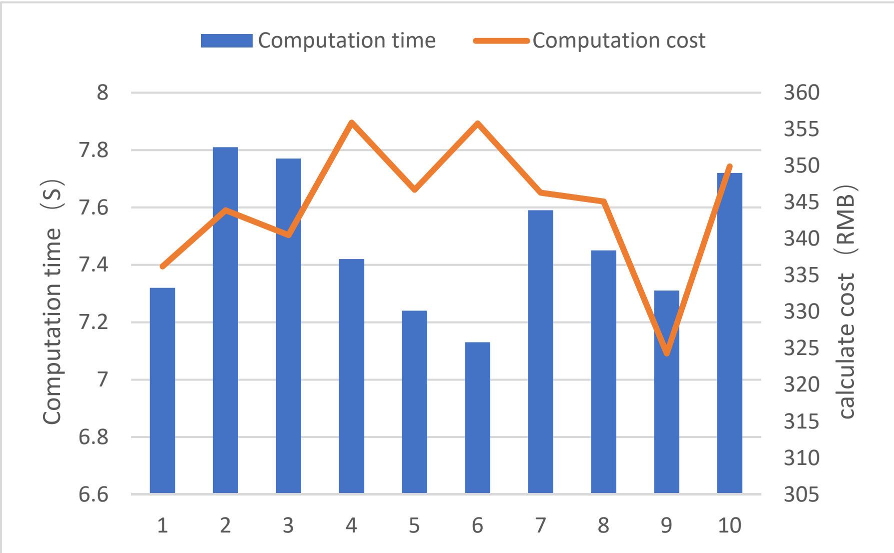

Figure 2. Schematic diagram of calculation results

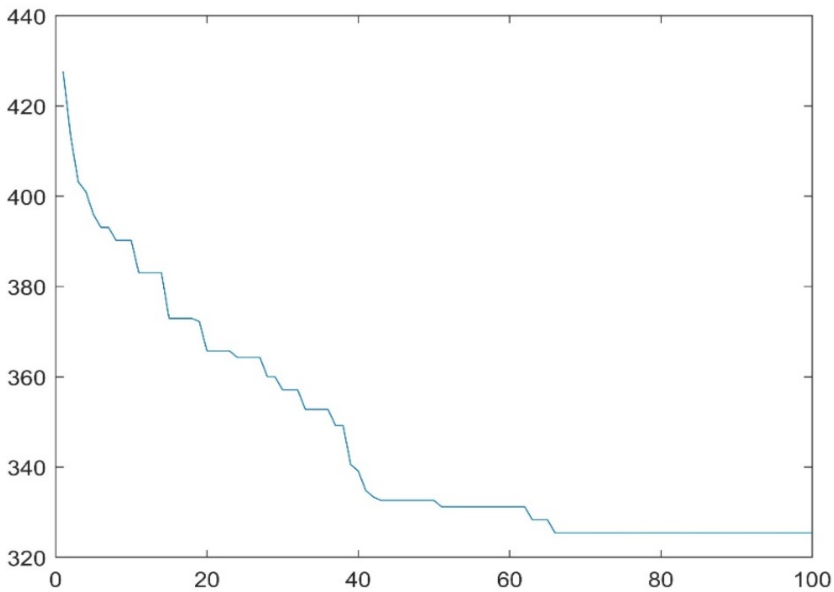

Figure 3. Algorithm convergence graph

Figure 2. and Figure 3. are the result graphs of calculation examples and algorithm convergence graphs set in this paper.Due to the large amount of data of vehicle allocation, this paper only writes the allocation scheme of three vehicles.It can be concluded from the result figure that, among the ten operations, the calculation result at the ninth run time is the smallest, with a minimum value of 324.3 yuan. As shown in the algorithm convergence chart, the calculation result of this time is reasonable. The corresponding set card allocation scheme is shown in the table below:

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Table 2. Partial vehicle allocation results table

Run number	Crossover probability	Mutation probability	Vehicle Allocation Results
1	0.9	0.1	Vehicle 1 first packs transport missions 1 and 5, then packs transport missions 2 and 6;Vehicle 2 Packaged Transport Missions 3 and 10;Vehicle 3 packs transport missions 4 and 7 first and then pack transport missions 8 and 9.
2	0.9	0.1	Vehicle 1 first packs up transport missions 1 and 3, then packs transport missions 2 and 7;Vehicle 2 first packs transport missions 5 and 9, then packs transport missions 8 and 10;Vehicle 3 Packaged Transport Missions 4 and 6.
3	0.9	0.1	Vehicle 1 first packs transport tasks 5 and 8, then packs transport tasks 9 and 10;Vehicle 2 Package Transport Missions 3 and 7;Vehicle 3 first packs up transport missions 1 and 4 and then packs transport missions 2 and 6.

3. Conclusion

Based on the subdivision and quantification of the number of transhipment containers, this paper builds a nonlinear programming model and takes two docks in Yangshan Port Area of Shanghai Port as an example to solve the problem by using the improved genetic algorithm. The main contributions are as follows:

(1) Based on the consideration of practical problems, this paper builds an optimization model of inter-terminal container transfer, and provides a vehicle allocation scheme when the transport cost is the least;(2) Through the improved genetic algorithm, a genetic algorithm that conforms to the reality and satisfies the research problem is designed. This algorithm can realize the vehicle allocation scheme with the minimum container transport cost;(3) The above Yangshan Port Phase 2 and Phase 3 terminals are taken as examples to provide theoretical decision-making basis for container transshipment between terminals.

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