

Study on Optimization of Empty Container Transport in Multimodal Transport of Containers

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Abstract

Through the integration of the resources of various new cooperation modes, this paper puts forward the optimization method of empty container transportation based on the participation of container ports, that is, the advantages of container ports in obtaining empty container resources when cooperating with other parties are utilized to provide empty container demand for shipping companies as the role of container leasing companies. An integer programming model aiming at minimizing the total cost of empty container transportation in shipping companies is established. The sensitivity analysis method is used to analyze the results of the example, and it is proved that the optimization mode of empty container transportation is helpful to reduce the total cost of empty container transportation and improve the service of empty container transportation, thus providing decision support for the cooperation of port and airline enterprises on empty container transportation.

Keywords

Container port; Multimodal transport; Shipping company; Empty container dispatch; Lingo.

1. Introduction

In recent years, the proportion of container transport in the total volume of shipping is increasing, and container transport has become the core of maritime transport. However, due to the imbalance of goods flow around the world, the contradiction between container supply and demand has become prominent. With the increase of empty container allocation quantity and the decrease of container utilization efficiency, the allocation cost of empty container increases and the inventory of empty container increases at the port. At the same time, it indirectly affects the number of shipping line container equipment and container rental quantity, resulting in the increase of the total cost of container transportation. Cost control and reduction in empty container transportation have become the key factors that affect the operation of shipping enterprises.

At present, qualitative investigation method and experience are mainly adopted to solve the problems in empty container management. Although it is impossible to avoid the distribution of empty containers in the case of unbalanced cargo movement, it can reduce the container loading and transportation costs of the airline. Through a reasonable way of container leasing, so as to reduce the cost of transportation, improve the competitiveness and economic benefits of shipping companies.

2. Overview of empty container transportation

2.1 Causes of empty containers

There are many reasons for empty container transport. The imbalance between container supply and demand is the direct cause of empty container transport. The specific reasons are as follows:

- (1) The imbalance of import and export supply leads to the imbalance of the proportion of import and export containers, resulting in the problem of empty container transportation.
- (2) Due to trade deficit and seasonal changes, the flow of containers is unbalanced, resulting in empty container transportation. At present, almost all liner routes in the world exist because of seasonal changes in cargo transportation and trade imbalance between countries or regions at both ends of the routes.
- (3) Due to the different nature of import and export goods, containers of different specifications need to be used, resulting in a shortage of containers of different specifications. It is necessary to empty the containers and reposition the same specifications to meet the needs of different goods.
- (4) Due to empty container transportation production management reasons, such as the circulation of documents, poor circulation, affecting the allocation and turnover of empty container, etc.
- (5) Other reasons: for example, in consideration of the cost of container repair and the requirements of repair boxes, the shipping company will transfer empty containers to areas with low cost and high quality for repair.

2.2 Main factors affecting empty container transportation

2.2.1 Container loading quantity

The amount of container loading is the direct factor that affects the distribution and transportation of empty containers. If there are not enough containers on a route, there will be a large demand for container allocation and transportation.

2.2.2 Number of containers and rate of hire

When a large number of empty containers are needed, liner companies have two options: hire or transfer. When the occupancy rate is high, the liner company will allocate. Instead, containers need to be rented in an emergency, and liner companies can use both options.

2.2.3 Container sales price

Liner lines can buy containers directly, especially in China, if they are sold at reasonable prices and demand for empty containers is high. Although the cost of buying a container is much higher than renting or moving an empty container, this method is not usually used.

2.2.4 Container management level

The low level of container management is the main reason for empty container distribution. It is necessary to improve the level of container management.

2.2.5 Frequency of port calls

The frequency of docking affects the voyage time of empty container. The allocation and transport of empty containers must be determined by the liner transport plan. The liner transport plan must be clear before the distribution plan is made.

2.2.6 Ocean route mode

Route mode is an important factor that affects the allocation and transportation of empty containers. It determines which container ship should load empty containers and how to load them.

2.3 Empty container transportation solutions

Combined with the characteristics of empty container transport and the main reasons for empty container transport, the main measures to solve this problem are as follows:

- (1) To implement share cooperation between container shipping companies, because every company in the port or supply of goods volume and box packaging standard requirements and changing, the backlog of some boxes may be other liner company box needs a larger place, on the basis of careful planning the deployment of each other can achieve the goal of win-win or multi-win. The mutual cooperation among the containers of liner companies will improve the utilization rate of the container

equipment of each partner, reduce the empty container transportation and reduce the cost of container management.

(2) Cooperation between shipping companies and container leasing companies. The method is used to solve the difference between production and consumption.

(3) Make full use of the supply of goods in the surrounding areas, speed up the speed of goods operation, improve the efficiency of operation and reduce the operation cycle. For example, to provide preferential prices to the consigners, this method is mainly used to discount the agent price and reduce the loss of receipt and distribution of empty containers.

(4) To carry out multimodal transport and speed up container turnover: this method is mainly "self-reliance", which means to strengthen the collection and distribution system in the process of container circulation, control container transport time and speed up container turnover.

(5) Reasonable allocation of containers: according to the different transportation routes of the goods according to the batch, type and direction, the company shall reasonably determine the proportion of flexible container leasing, long-term leasing and self-purchase of containers in the process of equipping the containers, so as to improve the container turnover and improve the utilization rate.

3. Empty container management model

We use $A_i (i=1,2,3,4,5)$ to represent each cooperation mode in which the port participates in empty container transportation. The details are as follows:

A1: the shipping company may rent or store empty containers in a dock yard built by itself for a long time;

A2: container ports act as agents of empty containers on land for shipping companies;

A3: container ports cooperate with shipping companies as container owners;

A4: container ports cooperate with container leasing companies or container manufacturers to provide container sources for shipping companies;

A5: container ports cooperate with shippers or freight forwarding companies to share upstream container information.

In this paper, from the port to the identity of the container owners empty containers will be on loan to the shipping company's point of view, empty containers in port in scheduling optimization model is established, the basic principle is to replace the port container leasing company, the role of the shipping company only when the empty containers in dispatching on the empty containers to the container port leasing, and rental prices will less than the price of container leasing company. Empty containers in container ports come from the realization of A2, A4 and A5 cooperation. At the same time, the empty containers owned and leased by the shipping company are stored in the way of renting the port yard. Considering that the fixed assets of shipping companies have accounted for a large proportion of the company's investment, the strategy of building a yard to store empty containers is not considered. If container ports want to provide sufficient container sources for shipping companies, cooperation with shippers or freight forwarding companies is also essential. Therefore, the optimization mode M of empty container transportation with the participation of container ports is the comprehensive implementation of five cooperation modes, A1, A2, A3, A4 and A5.

3.1 Model assumptions

Generally, the model pursues three goals: cost minimization, profit maximization and service efficiency. The empty container transportation studied in this paper does not generate any direct benefits to shipping companies, so the model in this paper aims to minimize the total cost of empty container transportation.

The problem to be solved by the model in this paper can be described as a shipping company operating several ships at the same time on a certain route to transport between the same ports. Based on the unbalanced distribution of cargo flow, under the constraint condition of meeting the demand of heavy

container transportation and empty container, the strategies of empty container dispatching, renting and storage are comprehensively balanced to minimize the total cost of empty container dispatching under the condition of meeting the customer's demand for empty container.

When constructing the model, the following assumptions are given:

1. All heavy and empty containers shall be charged according to the 20ft specification of the same type;
2. Empty container supply and demand known, empty container supply and demand known;
3. All containers are considered available at any point in time, regardless of the container itself;
4. There is no transshipment port, empty container transfer is a direct transport from supply to demand;
5. Excluding empty container turnaround time at the port, that is, only the time spent in sea transport;
6. Containers can be rented without restrictions, that is, at any time any port can rent an unlimited number of containers;

3.2 Definition of parameters

n : Decision cycle

i : empty container supply port; j : empty container demand port;

S : Set of empty container supply points, $\forall i \in S$

D : Set of empty container demand points, $\forall j \in D$

K : Assembly of ships, $\forall k \in K$

C_{ij}^{kt} : Unit empty container transportation cost for ship k from port i to port j at time t ;

CL_i^t : Unit dry charges for empty containers at port i at time t ;

Cr_i^t : The rate per container day for renting containers from port i at time t ;

CS_i^t : Unit empty container storage charges at port i at time t ;

F_{ij}^{kt} : Vessel k 's heavy box traffic from port i to port j at time t ;

S_i^t : Empty container supply at port i at time t ;

D_i^t : Demand for empty containers at port i at time t ;

T_{ij} : Transit time from port i to port j ;

U_{ij}^k : The maximum traffic of ships between ports i and j ;

Z_i^t : Empty container stock in port i at time t ;

X_{ij}^{kt} : At time t , ship k transfers the volume of empty containers from port i to port j ;

Y_i^t : The number of containers rented from port i at time t ;

Besides, Introduce parameter β_{ij}^{kt}

$$\beta_{ij}^{kt} = \begin{cases} 1 & \text{Ship } k \text{ Anchors at port } i \text{ at time } t, \text{ and port } j \text{ Anchors after port } i \\ 0 & \text{Others} \end{cases}$$

3.3 Determination of objective function

In this paper, an optimization model is proposed to minimize the total cost of empty container transportation. The total cost is divided into three parts: the cost of empty container transportation, the cost of leasing containers to the port and the cost of stacking.

3.3.1. Empty container transportation cost

Empty container transportation cost = volume of container transportation x (maritime transportation cost + unit dry cost of empty containers and bags)

Among them, the dry cost of unit empty containers includes the freight and handling cost of unit empty containers from the storage yard or inland freight station to the ship. The formula of empty container transportation cost is as follows:

$$M = \sum_{t=1}^{n_t} \sum_{k=1}^{n_k} \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} X_{ij}^{kt} \beta_{ij}^{kt} (C_{ij}^{kt} + CL_i^t) \quad (1)$$

3.3.2. Rental cost

The cost of chartering containers is the cost that the shipping company rents containers from the port as the owner of empty containers.

Box rental cost = box rental volume × number of days occupied by box rental × box day rate

In which, the number of days for renting containers = length of decision period - time point for renting containers

The formula of box rental fee is as follows:

$$N = \sum_{t=1}^{n_t} \sum_{i=1}^{n_i} Cr_i^t Y_i^t (n - n_t) \quad (2)$$

3.3.3. Storage cost

Storage cost is the storage cost of empty containers owned and leased to the port during the planning period.

Deposit cost = deposit amount x deposit rate

The formula of deposit fee is as follows:

$$P = \sum_{t=1}^{nt} \sum_{i=1}^{ni} CS_i^t Z_i^t \quad (3)$$

The sum of the above three costs is the objective function:

$$C = \text{MIN} \left(\sum_{t=1}^{n_t} \sum_{k=1}^{n_k} \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} X_{ij}^{kt} \beta_{ij}^{kt} (C_{ij}^{kt} + CL_i^t) + \sum_{t=1}^{n_t} \sum_{i=1}^{n_i} Cr_i^t Y_i^t (n - n_t) + \sum_{t=1}^{nt} \sum_{i=1}^{ni} CS_i^t Z_i^t \right) \quad (4)$$

3.4 Determination of constraints

3.4.1 Nonnegative constraint

$X_{ij}^{kt}, Y_i^t, Z_i^t, S_i^t, D_i^t, F_{ij}^{kt}, U_{ij}^k$ are all non-negative integers.

3.4.2 Transportation capacity constraints

The amount of heavy and empty containers carried by the ship shall not exceed the maximum carrying capacity of the ship. The formula is expressed as follows:

$$\sum_{i=1}^{n_i} \sum_{j=1}^{n_j} X_{ij}^{kt} \beta_{ij}^{kt} + \sum_{i=1}^{n_i} \sum_{j=1}^{n_j} F_{ij}^{kt} \beta_{ij}^{kt} \leq U_{ij}^k \quad (5)$$

3.4.3 Constraints on the current empty container inventory

Current empty container quantity = empty container quantity + empty container supply quantity + rental container quantity - empty container export quantity - empty container transportation volume at the previous time point. The formula is as follows:

$$Z_i^t = Z_i^{t-1} + S_i^t + Y_i^t - D_i^t - X_{ij}^{kt} \tag{6}$$

4. Case study

4.1 Example description

We take a shipping company operating a fixed route as an example. It is known that there are 6 ports and 4 ships on this route, and the whole sailing time is 14 days and nights. The main data are shown in the table below:

Table 1 Initial stock of empty containers in port (unit: TEU)

i	1	2	3	4	5	6
Z0	100	100	100	150	150	200

Table 2 Empty container transportation cost (unit: USD/ TEU)

i \ i	1	2	3	4	5	6
1	0	3	5	12	18	25
2	3	0	2	9	15	23
3	5	2	0	7	13	20
4	12	9	7	0	8	10
5	18	15	13	8	0	0
6	25	23	20	10	5	0

Table 3 Transportation time (unit: day)

i \ i	1	2	3	4	5	6
1	0	1	2	2	7	9
2	0	0	1	3	6	8
3	2	0	0	2	6	8
4	4	0	2	0	5	7
5	6	0	5	7	0	4
6	9	0	7	6	4	0

Table 4 Empty container demand (unit: TEU)

i \ t	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	300	0	0	0	0	0	0	260	0	0	0	0	0	0
2	0	240	0	0	0	0	0	0	210	0	0	0	0	0
3	0	0	120	0	0	130	0	0	0	120	0	0	130	0
4	0	0	0	100	100	0	0	0	0	0	80	80	0	0
5	80	90	0	0	0	0	0	0	160	0	0	0	0	0
6	0	0	0	0	190	0	0	0	0	0	0	0	0	0

Table 5 Empty tank supply (unit: TEU)

$\begin{matrix} t \\ i \end{matrix}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	100	0	0	0	0	0	0	80	0	0	0	0	0	0
2	0	110	0	0	0	0	0	0	100	0	0	0	0	0
3	0	0	70	0	0	50	0	0	0	80	0	0	80	0
4	0	0	0	100	90	0	0	0	0	0	100	90	0	0
5	170	170	0	0	0	0	0	0	200	0	0	0	0	0
6	0	0	0	0	300	0	0	0	0	0	0	0	0	0

Table 6 Rental cost (unit: USD / TEU / day)

$\begin{matrix} t \\ i \end{matrix}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	4.8	5.2	6	5.6	4.8	6	5.6	5.2	5.2	4.8	4.8	4.8	4.8	4.8
2	3.6	4	4	4	4.4	3.6	4	4.4	4.8	4.4	4.4	4	4	4
3	4.8	4.4	4.4	4.8	5.2	4.4	4	3.6	4	4.4	4.4	4.4	4.4	4.4
4	4	3.6	3.6	3.6	4	4	3.6	3.6	3.6	3.6	3.6	3.2	3.6	3.6
5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
6	4	3.6	3.2	3.2	3.2	3.6	3.6	3.6	4	3.6	3.6	3.2	3.6	3.6

Table 7 Storage cost (unit: USD / TEU / day)

$\begin{matrix} t \\ i \end{matrix}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2	1.5	1	1	1.5	1.5	1.5	2	1.5	1.5	1	1	1.5	1.5	1.5
3	1.5	1.5	2	1.5	1.5	2	1.5	2	2	1.5	2	1.5	2	2
4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5	2.5	2.5	2.5	2	2	1.5	2	2	2	2.5	2	2	2	1.5
6	2	2	2.5	3	2.5	2.5	2.5	2	2	2	2.5	2	2	2

Table 8 Unit dry cost of empty bags (unit: USD / TEU)

$\begin{matrix} t \\ i \end{matrix}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	30	30	30	30	30	30	30	30	30	30	30	30	30	30
2	29	29	29	29	29	29	29	29	29	29	29	29	29	29
3	32	32	32	32	32	32	32	32	32	32	32	32	32	32
4	34	34	34	34	34	34	34	34	34	34	34	34	34	34
5	32	32	32	32	32	32	32	32	32	32	32	32	32	32
6	28	28	28	28	28	28	28	28	28	28	28	28	28	28

4.2 Calculation results

Use lingo 9.0 to calculate the above example, write a program and run it. The result window is as shown in the figure. The final objective function is 41047.30 dollars. The amount of empty container transfer is shown in table 9. The figure in the table shows that Article k the number of empty containers transferred from port I to port J at time t.

Table 9 Operation results

k	1	1	2	3	3	3	4	4	4
i	1	4	1	4	5	5	5	5	6
j	2	1	2	1	1	3	1	3	3
t	1	4	8	11	2	2	9	1	5
X_{ij}^{kt}	6	75	40	42	88	12	70	30	26

The number of rented containers is shown in table 10. The Numbers in the table represent the number of rented containers at port I at time t.

Table 10 Container leasing amount

i	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
t	8	1	2	3	4	5	6	7	8	9	8	9	10	11	12	13
Y_i^t	1	13	12	12	13	14	6	4	6	14	8	6	14	2	13	9

4.3 Model evaluation

Through the analysis of the example in the above section, we can make the following evaluation on the optimization model of empty container transportation based on port participation:

1. This model is compared with the actual operation of shipping companies and coastal ports. The conclusions of the model are also in line with the actual situation and have practical significance for guiding the cooperation between ports and shipping companies in empty container transportation.
2. Lingo 9.0 is adopted as the model calculation tool, and the calculation speed is fast. Therefore, it is possible to optimize and improve the model. Therefore, we can refine the consideration factors on this basis, add restrictions, make the model more close to the actual situation, and increase the practicality.
3. Although the model reflects the characteristics of empty container transportation to a certain extent, it also has some shortcomings. For example, the model is lack of dynamic and real-time, the system calculation cannot be updated in real time with the changes of factors and parameters, and cannot timely reflect the dynamic nature of container transport.

5. Conclusion

This paper discusses the optimization of empty container transportation from the perspective of cooperation between container ports and shipping companies, and analyzes and demonstrates the empty container transportation system from the qualitative and quantitative perspectives. The new way of cooperation is to integrate the resources of all parties and promote the cooperation of all parties with the concept of win-win, so as to optimize the overall structure of empty container transportation and improve the regional competitiveness of ports, shipping companies, container leasing companies and other relevant parties. It is of great significance to solve the problem of empty container transportation in shipping industry.

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