Optimization of sea empty container reposition based on inventory control strategy

Yan Zhang

Shanghai Maritime University, Shanghai, China

202130510225@stu.shmtu.edu.cn

Abstract. In response to the problem of sea empty container transportation under random conditions, a comprehensive consideration is given to the conversion problem between short-term container rental and heavy empty containers. Through inventory control strategies, the inventory of empty containers at the port is optimized, and an optimization model for empty container transportation is established. The total cost obtained under inventory control strategy is lower than the total cost of empty container transportation without inventory control strategy. At the same time, adopting inventory control strategy can effectively improve the utilization rate of empty containers.

Keywords: empty container, inventory control, optimization model.

1 Introduction

With the globalization of trade and economy, container transportation has become one of the most widely used transportation methods in trade transportation due to its advantages of high efficiency and high cooperation. However, due to the imbalance of regional economic and trade, empty container transportation has become an inevitable problem in promoting the development process of container transportation industry. Even if empty container transportation is inevitable, it is necessary to carry out reasonable transportation of empty container resources to improve economic benefits.

Empty container research mainly focuses on multimodal reposition, multiple container types, cooperative alliances, and other aspects. In addition, some scholars have jointly optimized the problem of empty container storage and reposition from the perspective of inventory. Li et al. [1] analyzed the problem of empty container reposition at a single port and established an optimization model for empty container ownership Legros et al. [2] used inventory strategies to manage empty containers to save on their usage costs; Poo et al.[3]dynamically controlled the inventory cost and allocation cost of empty containers during transportation under random conditions, and developed dynamic strategies for empty container inventory control for shipping companies; Du F[4]studies the optimal empty container inventory at ports from the perspective of shipping alliances. Cai J X [5] considered the joint optimization of empty container

K. Elbagory et al. (eds.), *Proceedings of the 9th International Conference on Financial Innovation and Economic Development (ICFIED 2024)*, Advances in Economics, Business and Management Research 281,
https://doi.org/10.2991/978-94-6463-408-2_41

reposition and storage in the port group, and adopted an inventory control strategy to dynamically optimize the empty container inventory in the port group and public hinterland.

Based on the research on empty container transportation from different perspectives mentioned above, it can be found that existing research has the following problems:

(1) Existing research overlooks the factors of short-term container rental and return;

(2) Neglecting the mechanism of conversion between heavy and empty containers in estimating the number of empty containers;

(3) Lack of applying inventory control strategies to empty container transportation problems.

Therefore, this article will be based on the problem of sea empty container transportation under random conditions to establish an optimization model, comprehensively considering factors such as short-term container leasing and heavy empty container conversion. The advantages and disadvantages of total cost under the use of inventory strategy will be compared and analyzed.

2 Model construction

2.1 Assumptions

① Only Consider 20 foot standard containers;

②This article considers short-term container leasing, which incurs rental fees even if the containers are not returned in the next cycle, and the rental volume is not limited;

③ The heavy containers that arrive in this period will be unloaded at the beginning of the next cycle and become the current empty container supply;

2.2 Symbol Description

N : Decision stage; $n \in N$

P : A collection of all ports; $i, j \in P$

CP_{ij} : Unit empty container reposition cost from port i to port j.

CH_i Unit empty container storage cost at port i.

CR_i Unit empty container rental cost at port i.

X_{ij}^n The number of empty containers transported from port i to port j in n cycle.

R_i^n The number of leased containers at port i.

Q_i^n The number of return containers at port i.

D_i^n The demand for empty containers at port i ,which is a random demand that follows a normal distribution.

S_{ji}^{n} The number of heavy containers transported from port j to i.

W_{i}^{n} The difference between the outflow and inflow of empty containers at port i.

r_{i}^{n} The number of empty containers that have not been returned at port i.

2.3 Mathematical Model

Scenario 1: Inventory control strategy not used. The objective function (1) refers to minimizing costs consisting of three parts: the first part is reposition costs, the second part is leasing costs, and the third part is storage costs.

$$\min TC = \sum_{n}\sum_{i}\sum_{j} CP_{ij} X_{ij}^{n} + \sum_{n}\sum_{i} CR_{i}\left(R_{i}^{n} + r_{i}^{n}\right) + \sum_{n}\sum_{i} CH_{i} H_{i}^{n} \tag{1}$$

Constraints:

$$W_{i}^{n} = H_{i}^{n-1} + \sum_{j\in P} S_{ji}^{n-1} - D_{i}^{n} \tag{2}$$

$$H_{i}^{n} = \begin{cases} W_{i}^{n} - \sum_{j} X_{ij}^{n} - Q_{i}^{n} + \sum_{j} X_{ji}^{n}, W_{i}^{n} > 0 \\ W_{i}^{n} + R_{i}^{n} + \sum_{j} X_{ji}^{n}, W_{i}^{n} \le 0 \end{cases} \tag{3}$$

$$W_{i}^{n} + \sum_{j} X_{ji}^{n} \ge \sum_{j} X_{ij}^{n} + Q_{i}^{n}, W_{i}^{n} > 0 \tag{4}$$

$$R_{i}^{n} = 0, W_{i}^{n} > 0 \tag{5}$$

$$X_{ij}^{n} = 0, W_{i}^{n} \le 0 \tag{6}$$

$$Q_{i}^{n} = 0, W_{i}^{n} \le 0 \tag{7}$$

$$\sum_{j} X_{ji}^{n} + R_{i}^{n} \ge -W_{i}^{n}, W_{i}^{n} \le 0 \tag{8}$$

$$r_{i}^{n} = r_{i}^{n-1} + R^{n-1}{}_{i} - Q_{i}^{n} \tag{9}$$

$$Q_{i}^{n} \le r_{i}^{n-1} + R_{i}^{n-1} \tag{10}$$

$$X_{ij}^{n}, R_{i}^{n}, Q_{i}^{n} \in Z^{+} \tag{11}$$

Equation (2) shows the difference between the inflow and outflow of empty containers; Equation (3) represents the inventory of empty containers at the end of the cycle; Equation (4) represents the constraint on the number of empty containers retrieved and returned by the port; Equation (5) represents the constraint on the number of rented containers; Equations (6) and (7) represent the constraints on the number of empty containers retrieved and returned by the port; Equation (8) represents the constraint that satisfies the demand; Equation (9) represents the amount of unoccupied containers; Equation (10) represents the constraint of returning empty containers; Equation (11) represents a non negative constraint.

Scenario 2: Use bilateral inventory control strategy (D, U):

$$D_i^n \leq W_i^n - Q_i^n - \sum_j X_{ij}^n + \sum_j X_{ji}^n + R_i^n \leq U_i^n, W_i^n > 0 \tag{12}$$

$$D_i^n \leq W_i^n + \sum_j X_{ji}^n + R_i^n \leq U_i^n, W_i^n \leq 0 \tag{13}$$

Equation (12)(13) indicates that the port ensures that the inventory of empty containers after the operation is within the minimum and maximum threshold limits.

3 Example analysis and solution

Assuming that shipping companies transport goods between ports, where is a port node, the initial quantity of empty containers in the three ports is 200,170 and 300. The related cost are shown in Table 1(Unit is USD) and the random demand distribution are shown in Table 2.The values of D and U are set based on experience:

Table 1. Related costs.

	P1→P2	P2→P3	P1→P3
Transport cost	12	15	8
	P1	P2	P3
Storage cost	4	5	3
Rental cost	30	30	30

Table 2. Random demand distribution by port.

	P1	P2	P3
(μ,σ^2)	(200,20)	(150,20)	(300,20)

Based on the mathematical model established above, the randomness is reflected in randomly generating different requirements. lingo 18.0 was used for programming and solving. After more than 60000 iterations, local optima were effectively avoided, and the global optimal solution was obtained. Obtain corresponding transportation plans for two scenarios: Scenario 1 has a total transportation cost of $4040, and Scenario 2 has a total transportation cost of $2570; The specific cost comparison is shown in the table 3.

Table 3. Cost comparison.

Scenario	Storage cost	Rental cost	Transport cost	Total cost
1	640	3000	400	4040
2	455	1650	895	2570

Through the analysis of Table 3, it can be concluded that inventory control at ports can better cope with temporary container leasing caused by random demand, effectively reducing the cost of container leasing. As surplus empty containers are transported to ports with insufficient containers, the utilization rate of empty containers is improved, which correspondingly reduces the inventory cost of empty containers and leads to an increase in the reposition cost of empty containers.

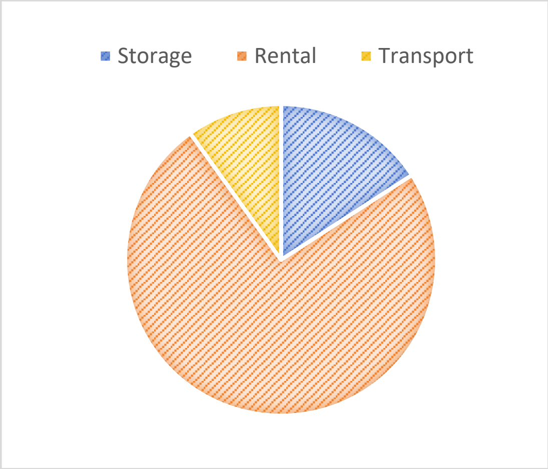

Fig. 1. Scenario 1

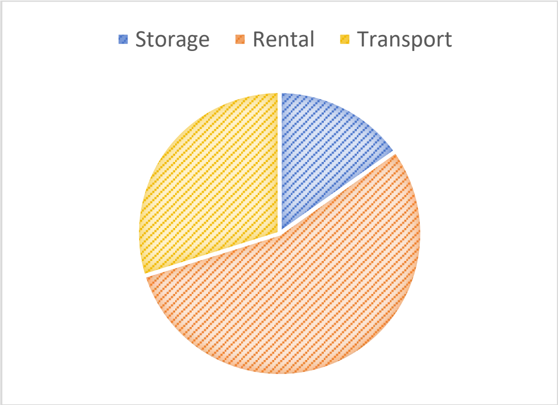

Fig. 2. Scenario 2

From the Figure 1 and 2 above, it can be seen that the proportion of each factor has changed slightly. The proportion of storage costs in scenario two has decreased. Due to effective control, inventory costs will not increase due to hoarding, while early storage increases transportation costs.

4 Conclusion

This article establishes a model and demonstrates through examples that using inventory control strategies to scientifically and reasonably transport empty containers can not only reduce the additional inventory and management costs caused by idle containers, improve the utilization rate of empty containers, but also avoid the need for short-term high rent due to random demand that cannot meet customer needs.

However, this article only focuses on the issue of empty container transportation at sea, and does not consider the possibility of returning containers from another location. Further research can combine multimodal transportation to study the comprehensive optimization of empty container transportation under multiple transportation modes, and consider the actual operating situation of short-term container rental, which is more practical.

References

1. Li J A, Liu K, Leung S C H, et al. (2004) Empty container management in a port with long-run average criterion. Mathematical & Computer Modelling,40(1-2): 85-100. Doi: 10. 1016/j.mcm.2003.12.005.
2. Legros B, Bouchery Y, Fransoo J. (2019) A time-based policy for empty container management by consignees. Production and Operations Management, 28(6):1503-1527. Doi:10.1111/poms.12996.
3. Poo M C P, Yip T L. (2019f) An optimization model for container inventory management[J]. Annals of Operations Research, 273(1/2): 433-453. Doi:10.1007/s10479-017-2708-8.
4. Du F. (2020) Research on Container Empty Container Inventory and Shipping Alliance Empty Container. Dalian Maritime University. Doi: 10.1007/s10479-017-2708-8.
5. Cai J X, Li Y B, Wang X H, et al. (2022) Joint optimization of empty container storage and transportation in port groups based on (D, U) control strategy[J]. Control and decision-making, 37(11):3012-3022. Doi: 10.13195/j.kzyjc.2021.0703.