Research on Transportation and Inventory Integrated Optimization Model Based on B2B Cross-Border E-Commerce

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Abstract—Starting from the integrity of B2B cross-border e-commerce transportation and inventory links, this paper takes the minimum total logistics cost as the optimization goal, constructs a joint optimization model of transportation and inventory based on B2B cross-border e-commerce, and applies the decomposition and coordination algorithm and improved genetic algorithm to solve the model. Finally, an example is given to verify the effect of the model on the optimization of B2B cross-border e-commerce transportation inventory cost, which provides reference for other cross-border logistics cost optimization problems.

Keywords-cross-border e-commerce; transportation route optimization; inventory management; genetic algorithm

1. Introduction

As the core section of cross-border e-commerce [1], the cost of cross-border e-commerce logistics has a huge impact on the revenue of enterprises and platforms. At the same time, the transport efficiency of logistics is also an important factor affecting consumer satisfaction [2]. Under the influence of the novel coronavirus pandemic, cross-border e-commerce platforms or companies must find solutions to reduce logistics costs and improve delivery timelines in order to ensure their competitiveness without compromising the consumer experience [3]. For a long time, the optimization of transportation and inventory has been carried out separately, but in fact, they influence each other and satisfy the law of antinomy. Therefore, it is of great theoretical value and practical significance to study the two links of transportation and inventory in the cross-border e-commerce logistics system as a whole to obtain the lowest total logistics cost [4-5].

This paper aims at the joint optimization of transportation and inventory links in B2B cross-border e-commerce logistics, and establishes a model with the lowest total cost as the optimization goal. In the process of solving the model, the complex model is firstly disassembled by the decomposition coordination algorithm, and then the optimal solution is obtained by the improved genetic algorithm. Taking a B2B cross-border e-commerce platform in China as an

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example, this paper analyzes the relevant data of platform operation by using the joint optimization model of transportation and inventory.

2. Establishment of Transportation Inventory Joint Optimization Model Based on B2b Cross-Border E-Commerce

Determining the transportation and inventory strategy with the goal of minimizing total logistics cost.

2.1 Problem Description

Cross-border e-commerce goods are transported from suppliers in the sending country to ports in the sending country, by sea to ports in the destination country, and then by road, rail or water to warehouses in the destination country. The goods transport process is shown in Figure 1.

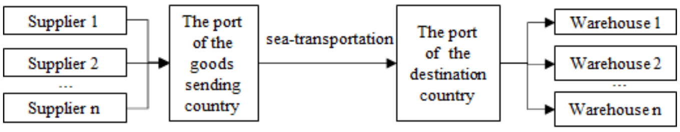

Figure 1. Diagram of Commodity Transportation Process.

This paper focuses on the joint optimization of transportation process and inventory from the port of the goods sending country to the warehouses of the destination country.

2.2 Problem Agreement

Logistics cost mainly includes inventory cost and transportation cost. Inventory cost includes fixed ordering cost, storage cost and shortage cost. Transportation cost includes shipping cost and transportation cost within the destination country [6-7].

2.3 Model Construction

This study aims to minimize the total logistics cost, and the decision variables of the model mainly include demand, delivery frequency and delivery time, delivery volume, lead time and transportation strategy.

1) Model assumption: To reduce unnecessary interference, make the following assumptions.

The order lead time of all goods is L. All goods are transported from the port of origin. Goods i follows a normal distribution with a mean of $\mu_i t$ and a variance of $\sigma_i^2 t$ over time t. Regardless of the mode of transport, the vehicle has a load limit, which is a capacity-limited path planning problem. Suitable vehicle on the market at any time. Order cost is fixed value. Each batch of transportation has a fixed transportation cost, such as customs clearance fee, document fee, etc. The demand for each item is known in advance and the calculation time is sufficient.

2) Symbolic interpretation.

Z represents the total transportation and inventory costs per unit time. G represents the procurement cost per unit time. O represents the fixed procurement cost per batch. g_i represents the single-batch procurement cost of goods. K_i^+ represents the inventory cost of goods per unit time. K_i^-represents the shortage cost of goods per unit time. k_i represents the inventory cost per unit of goods per unit time. k_i^-represents the shortage cost per unit of goods per unit time. C represents the transportation cost per unit time, where C_1 represents the shipping cost and C_2 represents the transportation cost in the destination country. j=1,2,3⋯⋯J represents the stage j of replenishment. i=1,2,3⋯⋯I denotes the type of commodity. R represents the warehouse set. R_j represents the set of warehouses that require goods in phase j. R_i represents the inventory level of goods supplied by one delivery. T_i represents the shortest replenishment period of the goods. T represents the shortest replenishment period. M represents the replenishment frequency of the entire system. m_i represents the replenishment frequency of the goods. Q_j represents the number of means of transport required for phase j. p=1,2,3⋯⋯P represents the warehouse number. q=1,2,3⋯⋯Q represents the transport unit number of the destination country. y_{ip} represents that a warehouse numbered p needs goods i. λ_{pqj} represents stage j, where goods are transported to a warehouse numbered p by a vehicle numbered q. λ_{opj} represents stage j, where goods are transported from a distribution center to a warehouse numbered p. λ_{psqj} represents the first stage in which a transport vehicle numbered q transports goods to warehouse s after the goods are transported to warehouse p. b_1 represents the carrying capacity of the ship. b_2 represents the loading capacity of the means of transport in the destination country.

3) Model establishment.

a) Inventory cost: Inventory cost includes fixed ordering cost, storage cost and shortage cost.

Fixed ordering cost:

$$G=O/t+\sum_{i=1}^{I} g_i/m_iT \qquad (1)$$

Storage cost:

$$K_i^+=k_i(R_i-\mu_iL-\mu_iT/2) \qquad (2)$$

Shortage cost:

$$K_i^-=\frac{k_i^-}{m_iT}\int_{R_i}^{\infty}(x_i-R_i)f(x_i,L+m_iT) \qquad (3)$$

b) Transportation cost: The shipping cost per unit time is C_1, the shipping cost per unit path length is c_1, and the shipping path length is d_1, the transportation cost per unit time in the destination country is C_2, the transportation cost per unit path length is c_2, the transportation path length is d_2, the transportation is carried by Q_j units, and the cost of each transportation is c_q. Therefore, the transportation cost can be expressed as

$$C=(c_1d_1+c_2d_2+c_qQ_j)/MT \qquad (4)$$

c) Model constraining conditions.

The model has the following constraints. The quantity of goods transported in a single batch is less than the capacity of the seagoing vessel, ensuring that each batch of goods is transported through the same carrier. The volume of goods transported in a single batch is less than the total load of the transport unit in the destination country. The capacity of overseas warehouse is greater than zero. The delivery cycle of goods is greater than zero. There are only two states of transport units in the destination country, transporting or not. Some other conventional constraints.

d) Inventory-transportation integrated optimization model.

Objective function:

$$\min Z = G + K_i^+ + K_i^- + C_1 + C_2 + C_3 = \frac{O}{t} + \sum_{i=1}^{I} \frac{g_i}{m_i T} + k_i \left(R_i - \mu_i L - \frac{\mu_i T}{2} \right) + \frac{k_i^-}{m_i T} \int_{R_i}^{\infty} (x_i - R_i) f(x_i, L + m_i T) + \frac{c_1 d_1 + c_2 d_2 + c_q Q_j}{MT} \quad (5)$$

Constraint condition:

$$\sum_{P \in R_j} \sum_{i=1}^{I} \mu_i T_i y_{ip} \lambda_{pqj} \le b_1 \sum_{p=1}^{P} \lambda_{opj} \quad (6)$$

$$\sum_{P \in R_j} \sum_{i=1}^{I} \mu_i T_i y_{ip} \lambda_{pqj} \le b_2 \sum_{p=1}^{P} \lambda_{opj} \quad (7)$$

$$\sum_{p=1}^{P_j} \lambda_{opj} = Q_j \quad (8)$$

$$\lambda_{pqj} = \begin{cases} 1 & \text{stage j,when transport q serves warehouse p} \\ 0 & \end{cases} \quad (9)$$

$$1 \le i \le I, 1 \le n \le N, Q_j < Q, T \ge 0 \quad (10)$$

3. Case analysis

This paper takes a B2B cross-border e-commerce platform in China as the research object. The platform mainly sells digital 3C, comprehensive department stores, maternal and child toys and other commodities, and has overseas warehouses in the United States, Spain and other countries. The platform purchases goods from Chinese suppliers, and then uniformly arrives at the port of the destination country from the domestic port by sea, and finally the goods are transported from the port of the destination country to the warehouses of the destination country.

3.1 Platform Basic Situation

By collecting the sales situation of the platform in the past six months, the 12 products with the largest sales volume in the destination country are selected for research. According to the literature and the data released by the platform, it is determined that L = 0.15, b_1 = 35000, b_2 = 1500, c_1 = 0.003, c_2 = 0.02, c_q = 500, O = 300, and the cost is calculated in US dollars. According to the sales volume in the past six months, the average demand μ and variance σ^2 of 12 kinds of commodities are derived. Compared with the storage cost, shortage cost and fixed ordering cost of similar goods on other B2B cross-border e-commerce platforms, the average method is used to obtain the costs of 12 kinds of goods on the platform. The parameters of the joint optimization model of commodity transportation and inventory of the platform are shown in Table 1.

Table 1 Parameters of Joint Optimization Model for Platform Commodity Transportation and Inventory

No.	μ (t/y)	σ^2 (t/y)	L (y)	warehous e cost(t/y)	shortage cost(t/y)	fixed ordering cost
1	16000	2500	0.15	2.80	55	24
2	5500	800	0.15	6.45	75	35
3	12500	1600	0.15	6.80	82	18
4	5000	1000	0.15	3.00	35	22
5	13800	1200	0.15	5.25	64	42
6	2500	300	0.15	9.30	96	33
7	8600	650	0.15	8.50	88	38
8	9200	880	0.15	18.00	130	18
9	11800	1400	0.15	6.90	78	26
10	4200	500	0.15	7.30	69	34
11	6300	750	0.15	4.30	52	27
12	8500	1350	0.15	13.50	113	41
others	b_1=35000, b_2=1500, c_1=0.003, c_2=0.02, c_q =500, O =300					

The platform has a total of 8 core transit warehouses in the destination country. For ease of calculation, a virtual distribution center is located at a high-speed port near 8 transit warehouses, and the distance between the high-speed port and 8 warehouses is known. The coordinate system is established with the distribution center as the origin, and the actual geographical location of the warehouses are mapped into the coordinate system. The distribution center and warehouse location are shown in Figure 2.

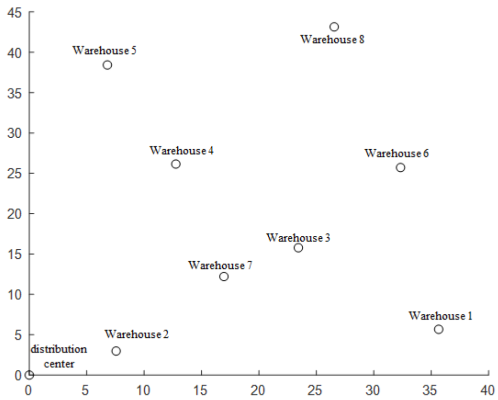

Figure 2. Distribution center and warehouse location.

Apply the model constructed in Section 3 to the scenario and solve it, the following calculation results are obtained.

3.2 Calculation Results

This study uses decomposition coordination algorithm and improved genetic algorithm to solve. Firstly, the nonlinear programming function fmincon in MATLAB is used to solve the inventory problem, and the results are shown in Table 2.

Table 2 Solution Results of Inventory Problem

No.	R_i	$T_i^{'}$	T_i	m_i
1	3086.53	27.92	30	1
2	1581.61	78.56	90	3
3	2398.90	32.83	30	1
4	1433.84	85.60	90	3
5	2642.30	29.74	30	1
6	802.58	112.21	120	4
7	2047.89	53.69	60	2
8	2191.62	65.21	60	2
9	2298.37	35.66	30	1
10	1022.81	55.73	60	2
11	1482.49	48.71	60	2
12	1982.79	57.19	60	2

It can be seen from Table 2 that the minimum delivery cycle of goods is 30 days. Goods 1, goods 3, goods 5 and goods 9 need to be delivered every cycle. Goods 7, 8, 10, 11, 12 need to be delivered every two cycles. Goods 2 and 4 need to be delivered every three cycles. Goods 6 need to be delivered every four cycles. The total inventory cost is $ 33452.27. In this study, a complete delivery cycle is 120 days, a complete transport cycle is divided into four stages, each stage of the optimal transport path to be solved. Using MATLAB software to use genetic algorithm to solve the vehicle distribution path in each stage, the results are as follows.

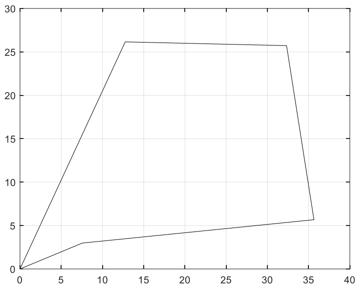

Figure 3. The Optimal Distribution Path in the First Stage.

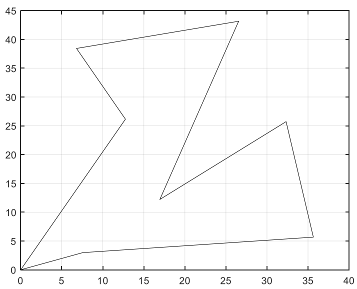

Figure 4. The Optimal Distribution Path in the Second Stage.

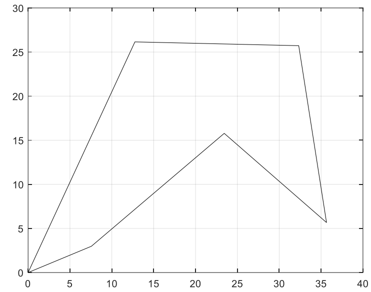

Figure 5. The Optimal Distribution Path in the Third Stage.

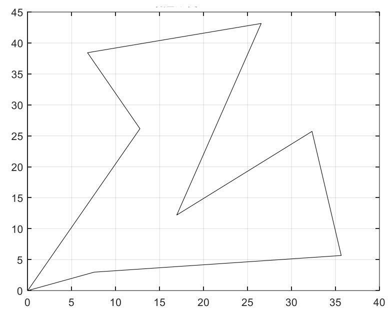

Figure 6. The Optimal Distribution Path in the Fourth Stage.

In Figure 3, the vehicle's path is virtual distribution center-warehouse 2-warehouse 1-warehouse 6-warehouse 4-virtual distribution center, the shortest path length is 105.34 km, and the transportation cost is $ 883633.3. In Figure 4, the vehicle's path is virtual distribution center-warehouse 2-warehouse 1-warehouse 6-warehouse 7-warehouse 8-warehouse 5-warehouse 4-virtual distribution center. The shortest path length is 172.59 km and the transportation cost is $ 1783165. In Figure 5, the path of the vehicle is virtual distribution center-warehouse 2-warehouse 3-warehouse 1-warehouse 6-warehouse 4-virtual distribution center. The shortest path length is 113.37 km and the transportation cost is $ 1177636. In Figure 6, the vehicle's path is the same as the second stage, but the transportation cost is different due to the different volume of goods transported, which is $ 1871919.

4. Conclusion

In the actual cross-border e-commerce logistics, transportation and inventory are closely linked and inseparable. This paper comprehensively considers the transportation and inventory costs of cross-border e-commerce logistics, establishes a joint optimization model of transportation and inventory based on B2B cross-border e-commerce, and uses the decomposition coordination algorithm and improved genetic algorithm to design the model solution method. Finally, a B2B cross-border e-commerce platform in China is taken as an example to verify the model and algorithm. The results show that the model has a good effect on the joint optimization of transportation and inventory of B2B cross-border e-commerce platform, and can provide reference for other cross-border logistics cost optimization problems.

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References

[1] P. Chen, (2022) Opportunities and Challenges Faced by Small Domestic Trade Enterprises in Transition to Cross-border E-commerce Enterprises. China Journal of Commerce, 19: 61-63.

[2] L.X. Xie, (2022) Transformation and Trend of Intelligent Logistics from the Perspective of Cross-border E-commerce-A Case Study of Jingdong and Cainiao Logistics. Journal of Wuhan Business University, 36:58-63.

[3] P. Julia, L. Olga, G. Valeriy, (2021) Automation of the solution to the problem of optimizing traffic in a multimodal logistics system. Advances in Intelligent Systems and Computing, 1258:255-261.

[4] S. Li, R. Xiu, M.J. Ji, (2021) Joint Optimization of Cold Chain Logistics Inventory Allocation and Transportation Route Based on Dynamic Change of Freshness. Systems Engineering, 39:69-80.

[5] D. Huang, (2021) Optimization Design of Inventory and Transportation System Based on Supply Chain. China Water Transport, 01:106-108.

[6] V. Oguzhan, (2022) Cost optimization in the (S- 1, S) backorder inventory model with two demand classes and rationing. Flexible Services and Manufacturing Journal, 34:101-124.

[7] Y.D. Xie, (2022) Research on Cold Chain Logistics Path Optimization Based on Improved Genetic Algorithm. Logistics Engineering and Management, 44:1-5.