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Research on Storage and Transportation Mode of Recyclable Express Empty Packaging based on Storage Location

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Abstract

Aiming at the phenomenon of unbalanced distribution of empty packaging and high circulation cost, this paper will build a suitable storage and transportation mode to meet the needs of storage and transportation and reduce the circulation cost. Based on the storage location of empty packaging nodes in the secondary logistics network structure, the storage and transportation models of empty packaging only stored in the regional distribution center and only stored in the city distribution center were constructed respectively, and the corresponding storage and transportation plans were obtained. According to the analysis, the storage location of the empty packaging of recyclable express needs to be determined according to the imbalance between supply and demand of the empty packaging in the region. With the increase of the imbalance between supply and demand, the cross-regional transport volume will also increase. The mode only stored in the regional distribution center can save the storage cost more than that only stored in the urban distribution center. In addition, the inventory of initial empty packaging also has a direct impact on the volume of empty packaging transportation, and it is necessary to consider the impact of its subordination demand data, storage rates and transportation rates.

Keywords

Storage and Transportation; Recyclable Express Packaging; Storage Location.

1. Introduction

In recent years, the state has also vigorously called on enterprises to use recyclable express packaging to promote the green transformation of express packaging, but due to the difference in internal and external trade between regions in China, the express packaging lacks initiative after the delivery of express goods to a certain region: As the delivery business is re-invested in the entire recycling system of express packaging, the problems of unbalanced distribution of empty packaging and mismatch between supply and demand of recyclable express appear, which also leads to the phenomenon of low efficiency, high recycling cost and blocked implementation of recyclable express packaging cycle.

In order to solve the problem of the implementation of recyclable express packaging, many scholars have launched an in-depth discussion. Regarding the location of relevant facility nodes, Zhou Xiaoye et al. proposed a method combining improved K-means clustering and set coverage to make full use of existing express delivery outlets as recycling points[1]. Xu Juan constructed and compared the recycling system in the case of new construction and expansion of existing logistics facilities[2]. Couto et al. in order to solve the problem of high cost in the existing reverse logistics system, proposed a reverse logistics location model aiming at wide service popularization, high recovery income and high participation to choose the number and location of distribution centers and functional centers[3]. In terms of logistics network design and optimization, Li R Y et al. proposed a distribution and recycling network of circular express packaging with positive and reverse mixing, and designed an algorithm based on Lagrange

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relaxation and column generation to solve the corresponding mathematical model[4]. Demirel et al. designed a general recycling network and established a mathematical model for recycling packaging considering carbon emissions from the perspectives of environmental protection and economic value[5]. Accorsi et al. proposed to incorporate life constraints into the closed-loop packaging network design model, showing how to guide the profitability of packaging manufacturers and the long-term sustainability of closed-loop networks[6]. In terms of recycling path optimization, Soysal et al. combined inventory management and path optimization, and proposed an optimization model for recyclable packaging closed-loop inventory path problem[7]. Li Jiabin et al. respectively established the inventory path model of picking up, sending and picking up mixed empty packaging in the packaging leasing system according to whether the recovered packaging could be directly delivered to customers[8]. In terms of express packaging recycling strategies, Xu Minli et al. discussed the market prospects of the "Internet +" recycling model[9], and Gong Yande et al. discussed the recycling decision-making of express packaging based on the two strategies of self-management or outsourcing[10]. Shi Chunlai et al. studied the influence of reward and punishment mechanism on manufacturers' cooperation strategy in the closed-loop supply chain with third-party recyclers[11]. In terms of profit distribution and supply chain coordination, Zheng Kejun et al. calculated and compared the profits of decentralized decision-making and centralized decision-making, and introduced a revenue-sharing contract to coordinate the interests of participants in the closed-loop supply chain of express packaging recycling, so as to improve the recycling rate of waste packaging[12]. However, the temporary problems after recycling and the further recycling problems have been little studied.

The general way to improve the mismatch between the current circular express empty packaging needs is to carry out reasonable transportation, taking into account the unity of logistics transportation, and the dual attributes of empty packaging transport goods attributes, transportation and inventory management is usually comprehensively considered[13]. Poo et al. discussed the dynamic control strategy of empty packaging inventory cost and empty packaging transportation cost in branch transportation[14]. On the basis of considering transportation and inventory costs, Duan Gang et al. added the impact of time window on the total cost, and designed a hybrid genetic simulated annealing algorithm to solve the problem [15,16].

To sum up, the current research on recyclable express packaging mainly focuses on the site selection of recycling-related facilities, recycling path optimization, recycling strategy, forward and reverse network optimization, and benefit distribution of related entities, etc., and few studies are used to solve the problem of mismatch between supply and demand and uneven distribution. In addition, most existing transport studies are conducted from the perspective of inventory holding control, and there are few literatures on transport studies from the perspective of inventory storage location.

Therefore, according to the characteristics of recyclable express packaging, this paper selects the common secondary logistics network structure composed of regional distribution center and urban distribution center as the research object. On the basis of meeting the demand of empty packaging transportation, it explores where the empty packaging of recyclable express is stored in the above network structure to save the total cost of the entire storage and transportation operation.

2. Problem Description

In the process of recyclable express packaging cycle, due to the difference in internal and external trade between regions, there is a gap between the amount of recyclable express empty packaging and the demand of many nodes in the express network structure, some nodes will

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accumulate a large amount of unnecessary empty packaging, and some nodes will be in shortage of empty packaging; In order to cope with the randomness of business needs, empty packaging inventory is usually stored to meet this uncertainty, which location should be stored, and how to plan the empty packaging transportation plan after storage, this paper will study the problem. The specific description is as follows:

In the secondary logistics network structure composed of m regional distribution centers and i city distribution centers, the operation process of bad express empty packaging can be transferred and temporarily stored in the above network structure. Only each city distribution center i has direct supply and demand for empty packaging each cycle, while the regional distribution center has no direct demand and supply for empty packaging. The supply and demand of the regional distribution center comes from the various urban distribution centers within its region.

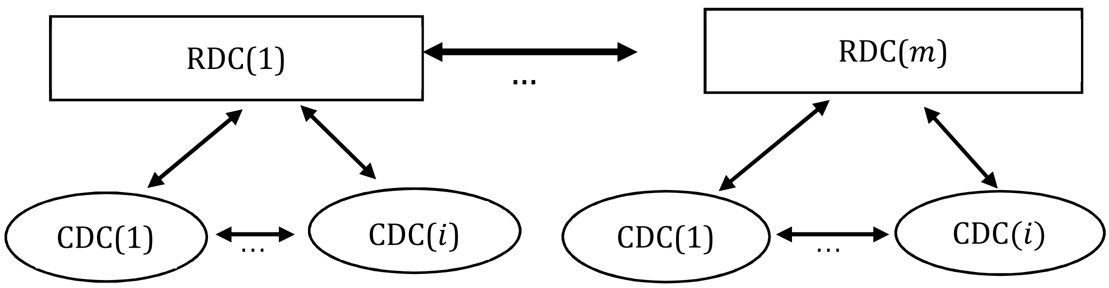

Figure 1. Structure diagram of the packaging cycle network for circular delivery empty

Represents the flow of empty packaging.

RDC(m): Regional distribution Center m.

CDC(i): Regional distribution Center i.

This paper aims to minimize the total inventory cost and total transportation cost in all cycles, combined with the heavy empty packaging transformation of each city distribution center, the inflow and outflow flow balance of each node and other constraints, to build a corresponding storage and transportation model, and construct and compare three different empty packaging storage modes. That is, it is only stored in the city distribution center, only stored in the regional distribution center, and the city distribution center is also stored together with the regional distribution center, which storage mode has a smaller total cost.

3. Model Construction

3.1. Assumptions and Assumptions

1) For the express packages transported to the urban distribution center i in the previous cycle, the empty express packages signed for recycling will all be supplied as the empty packages of the urban distribution center i in the current cycle, regardless of the damage, stains and other conditions of the recovered packages.

2) Temporary rental of empty packaging is not considered.

3) The transportation between each node arrives at the same period.

4) If the regional distribution center and the city distribution center set up empty packaging inventory, there is no limit to its inventory capacity.

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3.2. Parameter Settings and Variable Description

Symbol	Meaning
Parameter	
$R = \{1, \ldots, m, n\}$	Set of regional distribution center
$N = \{1, \ldots, i, j\}$	Set of city distribution center
$T = \{1, \ldots, t\}$	Set of time periods
Q_m^t	The amount of empty packaging supply of regional distribution center $m \in R$ in time period $t \in T$
q_i^t	The amount of empty packaging supply of regional distribution center $i \in N$ in time period $t \in T$
D_i^t	The amount of empty packaging demand of regional distribution center $m \in R$in time period $t \in T$
d_i^t	The amount of empty packaging demand of regional distribution center $i \in N$ in time period $t \in T$
H_m^0	The amount of initial empty packaging of regional distribution center $m \in R$
H_m^t	The amount of empty packages held by the regional distribution center $m \in R$ at the end of the period $t \in T$
h_i^t	The amount of empty packages held by the city distribution center $m \in R$ at the end of the period $t \in T$
h_i^0	The amount of initial empty packaging of city distribution center $i \in N$
C_{ij}	Transport cost from city distribution center $i \in N$ to city distribution center $j \in N$， ¥/unit
C_{mn}	Transport cost from regional distribution center $m \in R$ to regional distribution center $n \in R$， ¥/unit
C_{mi}	Transport cost from regional distribution center $m \in R$ to city distribution center $i \in N$， ¥/unit
C_m^h	Storage rates for regional distribution Center $m \in R$, ¥/unit
C_i^h	Storage rates for city distribution Center $i \in N$, ¥/unit
ρ_{im}	If the city distribution center i belongs to the regional distribution center m, the value is 1; otherwise, the value is 0
ρ_{ij}	If the city distribution center ij belongs to the same regional distribution center, the value is 1; otherwise, the value is 0
Decision variable：	
X_{mn}^t	The amount of empty packages shipped from regional distribution center m to regional distribution center m in time period $t \in T$
X_{mi}^t	The amount of empty packages shipped from regional distribution center m to city distribution center i in time period $t \in T$
X_{im}^t	The amount of empty packages shipped from city i to regional distribution center m in time period $t \in T$
X_{ij}^t	The amount of empty packages shipped from city distribution center i to city j in time period $t \in T$
Derived variable：	
ω_i^t	The net flow of regional city center $i \in N$ in time period $t \in T$
Ω_m^t	The net flow of regional distribution center $m \in R$ in time period $t \in T$

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3.3. Mathematical Model

3.3.1. Scenario-1 Model

Scenario 1: Empty packaging is only stored in the regional distribution center, and the city distribution center does not have empty packaging inventory and the corresponding inventory capacity. When a city distribution center i has a transportation demand, it sends help to the regional distribution center where the city is located. If the regional distribution center cannot meet the urban demand in the region, it sends help to other regional distribution centers to meet the demand.

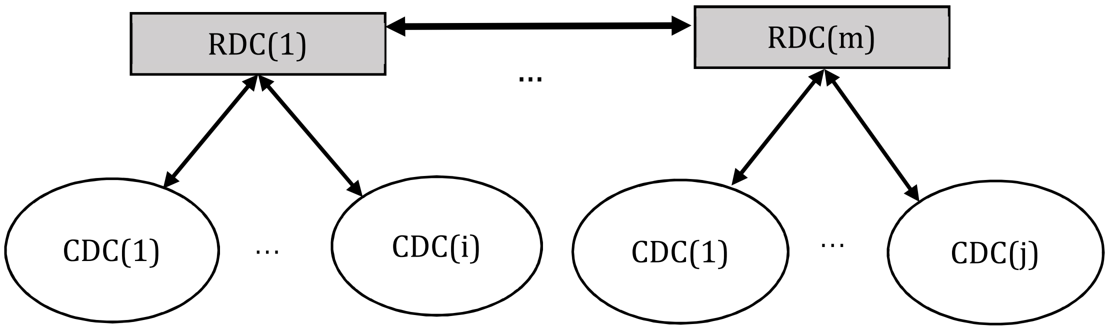

Figure 2. The network structure is saved only to the regional distribution center
Note: The gray fill indicates that the node has empty packaging inventory.

⟷ Represents the flow of empty packaging.

RDC(m): Regional distribution Center m.

CDC(i): Regional distribution Center i.

The objective function includes: (C1) empty package storage cost of regional distribution center; (C2) the transportation cost of the urban distribution center i to the regional distribution center m to which it belongs; (C3) the transportation cost of regional distribution center m to urban distribution center j within its scope; (C4) Transport cost between regional distribution centers mn. The specific mathematical model is as follows:

$$Min\ C = C1 + C2 + C3 + C4 \tag{1}$$

$$C1 = \sum_{t\in T}\sum_{m\in R} H_n^t C_m^h \tag{2}$$

$$C2 = \sum_{t\in T}\sum_{m\in R}\sum_{i\in N} X_{im}^t \tag{3}$$

$$C3 = \sum_{t\in T}\sum_{m\in R}\sum_{j\in N} X_{mj}^t C_{mj} \tag{4}$$

$$C4 = \sum_{t\in T}\sum_{n\in N}\sum_{m\in N} X_{mn}^t C_{mn} \tag{5}$$

S.T.

$$\omega_i^t = q_i^t - d_i^t, \forall i \in N, t \in T \tag{6}$$

$$X_{im}^t = \begin{cases} \omega_i^t \rho_{im}, \omega_i^t > 0, \forall m \in R, t \in T \\ 0, \qquad \omega_i^t \le 0, \forall m \in R, t \in T \end{cases} \tag{7}$$

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$$Q_m^t = \sum_{i \in N} X_{im}^t, \forall m \in R, t \in T \tag{8}$$

$$X_{mi}^t = \begin{cases} |\omega_i^t \rho_{im}|, \omega_i^t > 0, \forall m \in R, t \in T \\ 0, \qquad \omega_i^t \geq 0, \forall m \in R, t \in T \end{cases} \tag{9}$$

$$D_m^t = \sum_{i \in N} X_{mi}^t, \forall m \in R, t \in T \tag{10}$$

$$\Omega_m^t = H_m^{t-1} - Q_m^t - D_m^t, \forall m \in R, t \in T \tag{11}$$

$$H_m^t = \begin{cases} \Omega_m^t - \sum_{n \in R} X_{mn}^t, \ \Omega_m^t > 0, \forall m \in R, t \in T \\ \Omega_m^t + \sum_{n \in R} X_{mn}^t, \ \Omega_m^t < 0, \forall m \in R, t \in T \end{cases} \tag{12}$$

$$X_{mn}^t \leq min(|\Omega_m^t|, |\Omega_n^t|), \ \forall m, n \in R, t \in T \tag{13}$$

$$X_{mi}^t, X_{im}^t, X_{mn}^t, H_m^t \geq 0 \tag{14}$$

Constraints (6) The flow difference formula of urban distribution center i. Constraints (1-7) When the flow difference of the urban distribution center i is >0, there are excess empty boxes that can be transferred to the regional distribution center m. Constraints (8) In the regional distribution center m, the quantity transferred by all cities i to region m is the supply quantity of region m. Constraints (9) When the flow difference of the urban distribution center i is ≤0, the regional distribution center m needs to transport the air package to the urban distribution center i in demand within its range. Constraints (10) The demand of the regional distribution center m is the quantity transported by the regional distribution center m for all the urban distribution centers i within its scope. Constraints (11) The inflow flow of region m travels. Constraints (12) Inventory of region m. Constraints (13) Traffic transfer limit between regional distribution centers mn. Constraints (14) is non-negative integer constraint.

3.3.2. Scenario-2 Model

Scenario 2: Empty packaging is only stored in the city distribution center, and the regional distribution center does not have empty packaging inventory at this time, and the regional distribution center only plays the role of transit and circulation. When a city distribution center needs to have transportation needs, it will first be transferred from other city distribution centers in its region, if it is transferred through other city distribution centers in the same region, Still can not meet the demand, then seek other regional distribution center within the scope of the city distribution center of the empty packaging holdings for transport, at this time cross-regional transport needs to be transferred through the regional distribution center of each city.

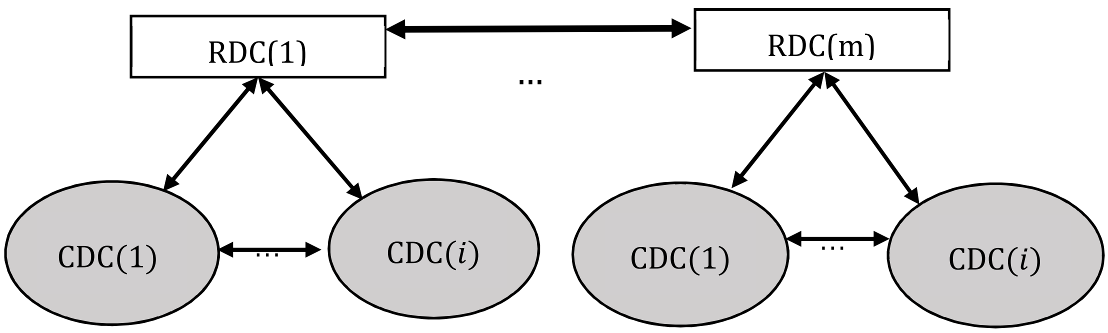

Figure 3. The network structure diagram is stored only in the city distribution center

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RDC(m): Regional distribution Center m.
CDC(i): Regional distribution Center i.
Note: The gray fill indicates that the node has empty packaging inventory.
⟷ Represents the flow of empty packaging.
The objective function includes (C1) the storage cost of the city distribution center; (C2) the transport cost between the intra-regional urban distribution centers ij + (C3) the transport cost of inter-regional transport, as follows:

$$Min\ C = C4 + C5 + C6$$
$$C4 = \sum_{t\in T}\sum_{m\in R} h_n^t C_i^h \tag{15}$$

$$\mathrm{C5} = \sum_{t\in T}\sum_{j\in N}\sum_{i\in N} X_{ij}^t \rho_{ij} C_{ij} \tag{16}$$

$$\mathrm{C6} = \sum_{t\in T}\sum_{m\in R}\sum_{j\in N} X_{im}^t C_{im} + \sum_{t\in T}\sum_{n\in N}\sum_{m\in N} X_{mn}^t C_{mn} + \sum_{t\in T}\sum_{n\in N}\sum_{m\in N} X_{mi}^t C_{mi}\rho_{ij} \tag{17}$$

S.T.

$$\omega_i^t = q_i^t - d_i^t, \forall i \in N, t \in T \tag{18}$$

$$h_i^t = \begin{cases} h_i^0 - d_i^t,\ t = 1, i \in N \\ \omega_i^t - \sum_{j\in N} X_{ij}^t \rho_{ij} - \sum_{m\in R} X_{im}^t \rho_{im}, \omega_i^t > 0, t \ge 2, m \in R, i \in N \\ \omega_i^t + \sum_{j\in N} X_{ij}^t \rho_{ij} + \sum_{m\in R} X_{im}^t \rho_{im}, \omega_i^t \le 0, t \ge 2, m \in R, i \in N \end{cases} \tag{19}$$

$$X_{ij}^t \rho_{ij} \le min(|\omega_i^t|, |\omega_j^t|),\ \ \forall i, j \in N, t \in T \tag{20}$$

$$X_{ij}^t = 0,\ \omega_i^t \le 0, \forall i, j \in N, t \in T \tag{21}$$

$$X_{im}^t \rho_{im} < \omega_i^t - \sum_{j\in N} X_{ij}^t \rho_{ij},\ \omega_i^t > 0, \forall i, j \in N, t \in T \tag{22}$$

$$X_{im}^t = 0,\ \omega_i^t \le 0, \forall i \in N, m \in R, t \in T \tag{23}$$

$$X_{mi}^t \rho_{im} = -\omega_i^t - \sum_{j\in N} X_{ji}^t \rho_{ji},\ \omega_i^t \le 0, \forall i \in N, m \in R, t \in T \tag{24}$$

$$\Omega_m^t = \sum_{i\in m} \omega_i^t \rho_{im}, \forall m \in R, t \in T \tag{25}$$

$$\Omega_m^t = \begin{cases} \sum_{n\in R} X_{mn}^t, & \Omega_m^t > 0, \forall m \in R, t \in T \\ -\sum_{n\in R} X_{nm}^t, & \Omega_m^t \le 0, \forall M \in R, t \in T \end{cases} \tag{26}$$

$$X_{mn}^t \le min(|\Omega_m^t|, |\Omega_n^t|),\ \forall m, n \in R, t \in T \tag{27}$$

$$X_{ij}^t, X_{mi}^t, X_{im}^t, X_{mn}^t, h_i^t \ge 0 \tag{28}$$

Constraints (15) - (17) are the objective functions, which represent storage cost, intra-regional transport cost and cross-regional transport cost respectively. Constraint (18) the flow

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difference of urban distribution center i. Constrain (19) the inventory of urban distribution center i. Constraints (20) - (21) Traffic transfer restrictions between urban distribution centers ij in the same region. Restriction (22) - (23) After the coordination of all urban distribution centers ij in the regional distribution center m is completed, the transportation volume that can needs to be transported to the regional distribution center is limited. Constraint (24) represents the amount of empty packaging that the regional distribution center m transfers to the urban distribution center i within its scope is the amount of empty packaging that the urban distribution center still needs after coordinated transportation through all other urban distribution centers j within the region. Constraints (25) The relationship between the flow difference of regional distribution center m and the flow difference of urban distribution center i within the region. Constrain (26) the relationship between the flow difference of regional distribution center m and the transfer volume of regional distribution center n. Restriction (27) Traffic transfer limit between regional distribution centers mn. Constraint (28) Non-negative integer constraint.

4. Model Solving and Numerical Experiments

4.1. Numerical Example Selection

This paper takes the Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Hebei economic circle as examples, representing three regional distribution centers respectively, and each regional distribution center has three urban distribution centers within its scope. Based on the historical data and actual operation conditions of these nine cities, this paper reduces the demand at a ratio of 1:10,000, and describes and assumes the demand for empty packaging. Assuming that the daily demand of empty packaging at each node is normally distributed, City 1 $N(130, 20^2)$, City 2 and City 3 $N(150, 20^2)$, City 4 $N(190, 20^2)$, City 5 and city 6 $N(200, 20^2)$, city 7, city 8 and city 9 $N(300, 20^2)$.

Table 1. The unit storage rate of each point

city name	CDC1	CDC2	CDC3	CDC4	CDC5	CDC6	CDC7	CDC8	CDC9
C_i^h	0.7	0.7	0.8	0.5	0.4	0.6	0.3	0.3	0.3
region name	RDC1	RDC2	RDC3						
C_m^h	0.33	0.2	0.18						

Table 2. The unit transportation rate for each period from $i\ to\ j$ and $m\ to\ n$

CDC-CDC	CDC1	CDC2	CDC3	CDC4	CDC5	CDC6	CDC7	CDC8	CDC9
CDC1	-	3	5	-	-	-	-	-	-
CDC2	3	-	4	-	-	-	-	-	-
CDC3	5	4	-	-	-	-	-	-	-
CDC4	-	-	-	-	5	7	-	-	-
CDC5	-	-	-	5	-	6	-	-	-
CDC6	-	-	-	7	6	-	-	-	-
CDC7	-	-	-	-	-	-	-	7	9
CDC8	-	-	-	-	-	-	7	-	8
CDC9	-	-	-	-	-	-	9	8	-

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Table 3. The unit transportation rate for each period from m to n

RDC-RDC	RDC1	RDC2	RDC3
RDC1	-	9	11
RDC2	9	-	12
RDC3	11	12	-

According to the type of goods belonging to the light goods of the bad express empty packaging, most of the relevant costs are calculated according to the volume. Considering the existing recyclable express empty packaging can be folded, the volume of 20 recyclable express empty packaging is estimated to be 1 cubic meter; According to this proportional relationship, combined with the actual market economy situation, the unit storage rate of each city distribution center and regional distribution center, as well as the unit transportation rate between nodes are set as follows.

The unit storage rate (Yuan/piece/period) for each period of each city distribution center and regional distribution center is.

4.2. Solution Results and Sensitivity Analysis

The model established in this paper is a mathematical model of integer programming. Heuristic algorithm or traditional solution method takes a long time and may not get the global optimal solution. In order to get the exact solution quickly, 0-1 variable and large integer M are introduced in this paper to linearize the interval constraints in the model. LINGO software is used to solve the models in the above three cases.

4.2.1. Analysis of Solution Results:

Table 4. Results of Model 1 and Model 2 calculations

Model	Storage cost	Transportation cost			Total cost
		$i-j$	$m-i$	$m-n$	
Model 1	1273	-	14256	12480	28009
Model 2	4728	1453	12880	21532	31585

Table 5. Dispatch schedule in mode 1 scenario

period	RDC-CDC	CDC 1	CDC 2	CDC 3	CDC 4	CDC 5	CDC 6	CDC 7	CDC 8	CDC 9	RDC(m)-RDC(n)
t=1	RDC1	148	166	163	-	-	-	-	-	-	0
	RDC2	-	-	-	201	200	204	-	-	-	
	RDC3	-	-	-	-	-	-	267	280	263	
t=2	RDC1	-89	-49	-61	-	-	-	-	-	-	0
	RDC2	-	-	-	0	21	18	-	-	-	
	RDC3	-	-	-	-	-	-	111	140	157	
t=3	RDC1	-108	-107	-67	-	-	-	-	-	-	RDC1-RDC3(235)
	RDC2	-	-	-	0	0	10	-	-	-	
	RDC3	-	-	-	-	-	-	99	107	128	
t=4	RDC1	-119	-103	-73	-	-	-	-	-	-	RDC1-RDC3(295)
	RDC2	-	-	-	31	0	0	-	-	-	
	RDC3	-	-	-	-	-	-	73	103	119	
t=5	RDC1	-84	-129	-59	-	-	-	-	-	-	RDC1-RDC3(302)
	RDC2	-	-	-	-23	31	49	-	-	-	
	RDC3	-	-	-	-	-	-	59	129	114	

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As can be seen from Table 4, in the context of this case, the total cost of mode 2 is 12.77% higher than that of mode 2. From the perspective of its cost composition, the more expensive land price of urban distribution center makes the storage cost higher. In addition, the relatively high cost is the cross-regional transportation cost, which is caused by the obvious imbalance between the supply and demand relationship between the selected case RDCs, the difference is large, resulting in the need for a large number of cross- regional transportation, and then the total cost is too high, but also let the mode 1 will store all the empty packaging in the city distribution center of this section of transportation, and did not cause reverse or repeated transportation. From Table 2 and Table 3 below, we can get the transportation plan of each cycle under the two modes, and the corresponding storage plan of each node combined with the initial inventory setting.

Table 6. Dispatch schedule in mode 2 scenario

period	RDC-CDC	CDC1	CDC 2	CDC 3	CDC 4	CDC 5	CDC 6	CDC 7	CDC 8	CDC9	1.RDC(m)-RDC(n) 2.CDC(i)-CDC(j)
t=1	RDC1	0	0	0	-	-	-	-	-	-	
	RDC2	-	-	-	0	0	0	-	-	-	
	RDC3	-	-	-	-	-	-	0	0	0	
t=2	RDC1	-89	-49	-61	-	-	-	-	-	-	1.RDC(1)-RDC(3)(298) RDC(2)-RDC(3)(27) 2.CDC(4)-CDC(5)(87)
	RDC2	-	-	-	0	-21	-18	-	-	-	
	RDC3	-	-	-	-	-	-	78	120	127	
t=3	RDC1	-108	-107	-12	-	-	-	-	-	-	1.RDC(1)-RDC(3)(227)
	RDC2	-	-	-	0	0	0	-	-	-	
	RDC3	-	-	-	-	-	-	99	0	128	
t=4	RDC1	-119	-103	-33	-	-	-	-	-	-	1.RDC(1)-RDC(3)(255) RDC(2)-RDC(3)(34) 2.CDC(4)-CDC(5)(70) CDC(6)-CDC(5)(68)
	RDC2	-	-	-	-34	0	0	-	-	-	
	RDC3	-	-	-	-	-	-	73	70	112	
t=5	RDC1	-104	-129	-44	-	-	-	-	-	-	1.RDC(1)-(RDC)3(239) RDC(1)-RDC(2)(38) 2.CDC(4)-CDC(5)(53)
	RDC2	-	-	-	10	0	28	-	-	-	
	RDC3	-	-	-	-	-	-	59	69	114	

Note: Positive values in the table indicate that the regional distribution center is transferred to the city distribution center. A negative value indicates that the city distribution center is transferred to the regional distribution center.

4.2.2. Sensitivity Analysis

1) The impact of different empty packaging demand, empty packaging return supply

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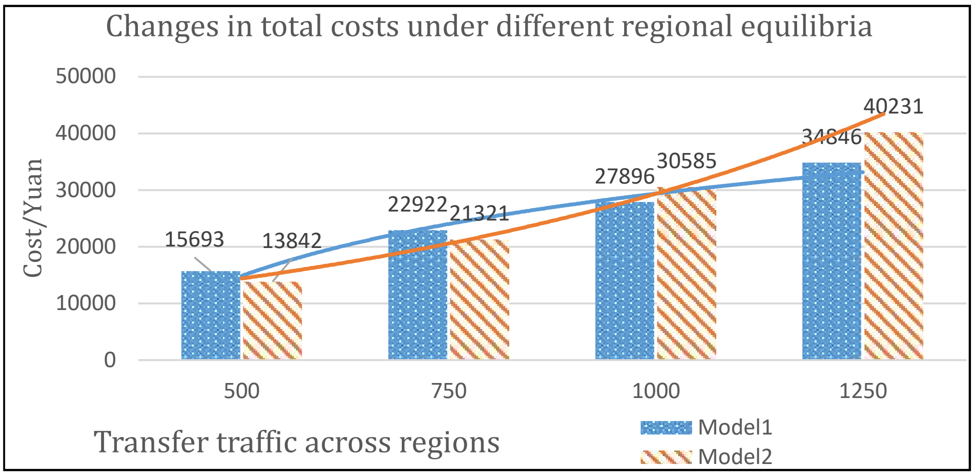

Figure 4. Changes in total costs under different regional equilibria

In the real business process, it is precisely because of the imbalance between the demand for empty packaging and the supply of empty packaging at each node, which leads to shortages and hoarding, and thus produces the demand for transportation. For a RDC, the demand for empty packaging within its own scope will also have a greater impact on the entire transportation mode. For example, the selected case is the obvious imbalance in the supply and demand distribution of empty packaging, and the cost of mode 1 is slightly less than the cost of mode 2. But as the figure below shows, when the balance of supply and demand distribution changes, the cost of the two different models changes.

As can be seen from the figure above, when the distribution of empty packaging in the RDC is more balanced, that is, the absolute value of Ω_m^t is small, then the cost of mode 1 is greater than that of mode 2, because most of the time-space packaging is carried out in the same RDC, and the empty packaging is stored in the city distribution center. It can reduce the reverse repeated transportation operations caused by mode 1 storing empty packages in the regional distribution center, thus reducing the total cost; As the empty packaging distribution in the RDC becomes more and more unbalanced, that is, when the absolute value of Ω_m^t becomes larger and larger, the balance within the RDC becomes more and more impossible to achieve, and more cross- regional transportation will be sought, so the empty packaging stored in the regional distribution center will save more storage costs because of its cheaper low price.

2) The impact of different initial inventories

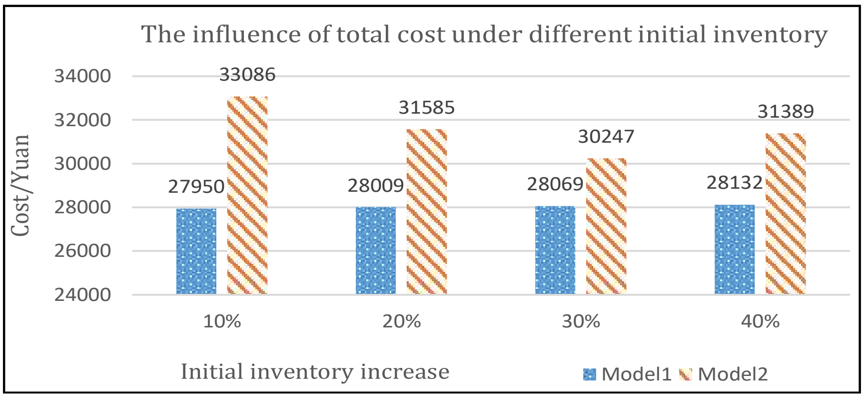

Figure 5. The change of total cost under different initial empty package quantity

When setting up the initial inventory for the urban distribution center or RDCal distribution center, in addition to placing the inventory according to the historical data of the first phase, it

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is also necessary to take into account the impact of the transportation demand in the subsequent cycle; The initial inventory setting will also have a direct impact on the subsequent storage transfer plan.

As shown in Figure 5, in order to ensure that the total amount of initial inventory set under the two modes is consistent, the initial inventory set amount of regional distribution center in mode 1 is the sum of the initial inventory set of all urban distribution centers in the same RDC in mode 2. As can be seen from the figure above, with the increase of the initial inventory setting, the total cost of mode 1 increases, but the fluctuation is small. That is because when the total transportation demand has been met, the main cost change is the increase of the storage cost of new empty packaging at the level of regional distribution center. As for the total cost of mode 2, when the initial inventory increases to 30%, the inventory cost decreases significantly. This is because the city distribution center sets up more initial empty packaging inventory, which reduces the inter- regional transportation volume in the subsequent cycle. However, when the increase volume reaches 40%, the total cost of Mode 2 no longer decreases. That is because the increase in storage costs brought by the new empty packaging is greater than the reduction in trans- regional transportation costs, so the total cost is no longer a downward trend.

3) The impact of different unit storage costs and transportation costs

While keeping other costs unchanged, the unit storage cost and unit transportation cost are changed respectively, and the impact of each cost analysis on the total cost is analyzed. It can be seen from the following table that unit storage cost and unit transportation cost are positively correlated with total cost. Therefore, when storage cost increases, empty packaging should be stored in regional distribution center as much as possible to reduce storage cost. When the transportation cost increases, the empty packaging should be stored in the city distribution center as much as possible to reduce the additional cost generated by transportation.

Table 7. Total cost changes under different unit storage costs and transportation costs

Argument	Growth ratio	Mode 1 Total cost	Mode 2 Total cost
Storage cost	10%	28136	32058
	20%	28263	32531
	30%	28399	33004
	40%	28517	44477
Transportation cost	10%	30682	34270
	20%	33356	36956
	30%	36029	39642
	40%	38703	42327

5. Conclusion

This paper starts with the storage location of recyclable express empty packaging in the logistics network structure, takes the two-level network composed of regional distribution center and urban distribution center as an example, and builds storage and transportation models under two different conditions: only storage in urban distribution center and only storage in regional distribution center. The plan period is 5 days. Through the commercial solution software LINGO, the corresponding empty package storage and transportation plan is solved.

According to the absolute value of the regional inflow and outflow Ω_m^t, the degree of imbalance between supply and demand of empty packaging is divided. When the degree of regional imbalance is small, the storage cost increase caused by mode 2: storing empty packaging in the urban distribution center closer to the demand side is smaller than that caused by mode 1: If the empty packaging is stored only in the regional distribution center, the reverse and repeated transportation cost is reduced. Therefore, mode 2: storing empty packaging in the urban distribution center is better than model 1: storing only in the regional distribution center. As the level of imbalance increases, the advantages of Mode 1 become more and more obvious, with its lower storage costs and closer to the demand side of the transport, compared to mode 2, more cost savings. In addition, mode 2: when empty packaging is only stored in the city distribution center, the initial empty packaging inventory increases within a certain range, which can reduce part of the transportation cost, and the reduction of this part of the transportation cost is more than the increase of the inventory cost, so that the total cost is less than mode 1. Therefore, the storage location of empty packaging needs to be determined according to the imbalance between supply and demand of the specific city, the amount of initial empty packaging, and the corresponding storage, transportation and transportation costs.

The further research direction is: considering the situation that empty packaging is stored in the city distribution center and regional distribution center, how to construct the corresponding storage and transportation model, and formulate the corresponding storage and transportation plan.

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