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Optimization Model of Remanufacturing Reverse Logistics Network with Double Channel Collection Inspection

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Abstract

With the coexistence of online collection and offline collection, the operation of remanufacturing reverse logistics network faces new problems, such as the quality difference of collection inspection and the market share of used products. Considering the quality difference of collection inspection between two channels, a network “collection/disassembling/remanufacturing” of remanufacturing reverse logistics is constructed, and the optimal transportation scheme of supply chain members are solved by LINGO 11.0, and the influences of the changes of used product market share and inspection error rate on the optimal values are further analyzed. The proposed model can effectively solve the optimization problem of daily operation of dual-channel remanufacturing reverse logistics network.

Keywords

Double Channel; Quality Difference of Collection-inspection; Remanufacturing Reverse Logistics; Network Optimization Model.

1. Introduction

With the emergence of online recycling channels for used products, a dilemma exists between online processing and offline utilization. In the study of reverse logistics distribution network model, Ma et al. (2004) minimized the transportation cost of remanufacturing logistics distribution network [1]. Based on the analysis of the remanufacturing reverse logistics network structure, Leng et al. (2005) established a remanufacturing reverse logistics network with a three-layer structure and selected the required nodes to refine the location of the logistics distribution network [2]. Zeng et al. (2006) established an optimization model of reverse logistics of used computers in consideration of government subsidies to solve the optimization problem of reverse logistics network of used computers in the Pearl River Delta [3]. Considering that there are many uncertain factors in the reverse logistics distribution network, Chen Yong et al. (2016) constructed a multi-objective uncertain reverse logistics network model and determined the facility location of third-party logistics enterprises [4]. Lu et al. (2017) constructed the model considering the random refurbishment proportion and pointed out that the improvement of refurbishment proportion would affect the optimization of logistics network [5]. Considering that there are many uncertain factors in the reverse logistics distribution network, Li et al. (2018) established a dual-channel reverse logistics network, considering the uncertainty of recycling quality, and achieved the goal of reducing inventory pressure by simulating the dual-channel model [6]. Guan et al. (2020) set up a multi-objective reverse logistics network model to reduce logistics costs for the problem of C2C e-commerce [7]. Di et al. (2021) built a model based on "carbon trading" and got the optimization path of reverse logistics distribution network. This model can optimize the network to reduce carbon emissions and increase the profits of enterprises at the same time [8].

On the basis of existing research, aiming at the quality difference of dual-channel recycling inspection, this paper constructs a remanufacturing reverse logistics network optimization model, applies LINGO 11.0 to solve the problem, and gives the optimal transportation scheme.

2. Problem Description

The remanufacturing reverse logistics network of dual-channel recycling and testing is composed of used product market (consumption area), recyclers and remanufacturers. Among them, used products in traditional recycling channel come from used product submitted by used product market to offline recyclers, who are responsible for quality inspection. The source of the used products in the online recycling channel is the used products submitted to the online recycling website by used product market, and the online recycling and processing center of the remanufacturer is responsible for quality inspection. After testing, both traditional recycling channel and online recycling channel will send the "remanufacturable products" to the disassembling center, and the "non-remanufacturable products" will be discarded. The remanufactured products disassembled by the disassembling center are sent to the remanufacturing factories, and the non-remanufactured products are sent to the incineration and landfill center.

In this structure, used product market(consumption area) is derived from the consumption area, through offline recyclers and online recycling and processing centers for quality inspection.Then they will detect " remanufacturable products" to the disassembling centers (dismantling center affiliated to the remanufacturers),and they will detect "remanufacturable products" to the incineration and landfill center. After disassembling the "remanufacturable products" obtained by disassembling centers, the real remanufactured products will be transported to the remanufacturing factories, and the real non-remanufactured products will be transported to the incineration and landfill center. The structure of remanufacturing reverse logistics network with double channel recycling inspection is shown in Fig 1.

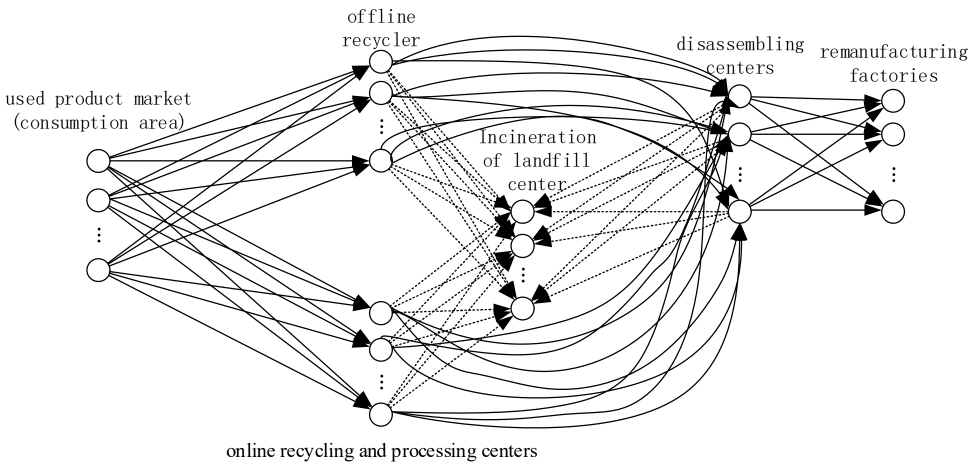

Fig. 1 The structure of remanufacturing reverse logistics network for double-channel recycling inspection

3. Model Building

3.1. Symbol Description

The sets, parameters and decision variables involved in this model are described below.

(1)Sets

k is the set of used product market (consumption area); l is the collection of disassembling centers; h is the collection of remanufacturing factories; i is the collection of offline recyclers; j is the collection of online recycling and processing centers; m is the incineration and landfill center.

(2)Parameters

The unit transportation cost from used product market(consumption area) k to offline recovery point i is expressed in C_{ki}; The unit transportation cost from offline recovery point i to disassembling Center l is expressed in C_{il} ; C_{lh} is the unit transportation cost from the disassembling centers i to the remanufacturing factory h; C_{kj} is the unit transportation cost from the used product market(consumption area) k to the online recycling and processing center j; C_{jl} is the unit transportation cost from the online recycling and processing center j to the disassembling center l; C_{im} is the unit transportation cost from the offline recycler i to the incineration and landfill center m; C_{jm} is the unit transportation cost from the online recycling and processing center j to the incineration and landfill center m; D_{ki} is the distance from the used product market k to the offline recycler i; D_{il} is the distance from the offline recycler i to the disassembling center l ; D_{lh} is the distance from the disassembling center l to the remanufacturing factories h; D_{kj} is the distance from the used product market(consumption area) k to the online recycling and processing center j ; D_{je} is the distance from the online recycling and processing center j to the disassembling center e; D_{im} is the distance from the offline recycler i to the incineration and landfill center m; D_{jm} is the distance from the online recycling and processing center j to the incineration and landfill center m; MP_i is the maximum recycling capacity of the offline recycler i; MP_j is the maximum recycling capacity of the online recycling and processing center j ; MP_h is the maximum processing capacity of the remanufacturing factories h; MP_l is the maximum disassembling capacity of the disassembling center l; α_i is the inspection error rate that the offline recycler i mistakenly detects the non-remanufactured used products as "remanufacturable products" and sends them to the disassembling center for disassembling; β_i is the inspection error rate that the offline recycler i mistakenly detects the remanufactured product as "non-remanufacturable products" and sends them to the incineration and landfill center m ; γ_i is the maximum remanufacturing capability rate of all used products recovered by the offline recycler i ; δ_i is the rate of dismantled used products in offline channels going to remanufacturing factories; α_j is the inspection error rate that the online recycling and processing center j mistakenly detects the non-remanufactured used products as "remanufacturable products" and sends them to the disassembling center for disassembling; β_j is the inspection error rate that the online recycling and processing center j mistakenly detects the remanufacturable product as "non-remanufactured products" and sends them to the incineration and landfill center; γ_j is the maximum remanufacturing capability rate of all used products recovered by the online recycling and processing center j; δ_j is the rate of the dismantled used products in the online channel going to the remanufacturing factories; X_k is the quantity of used products recycled by used product market k.

(3)Decision Variables

X_l represents the quantity of used products received and processed by the disassembling center l; X_{ki} is the quantity of recycled products transported from the used product market k to the offline recycler i; X_{il} is the quantity of used products transported from offline recycler i to disassembling center l; X_{lh} is the quantity of remanufactured used products transported from the disassembling center l to the remanufacturing factories h, where X_{l_1h} is the quantity of used products transported from the disassembling center l to the remanufacturing factory h in the traditional channel, X_{l_2h} is the quantity of used products transported from the disassembling center l to the remanufacturing factory h in the online channel; X_{kj} is the quantity of used products transported from used product market k to the online recycling and processing center j;X_{jl} is the quantity of used products transported from the online recycling and processing center j to the disassembling center l ; X_{im} is the quantity of non-remanufactured products transported from the offline recycler i to the incineration and landfill center m; X_{jm} is the quantity of non-remanufactured products transported from the online recycling and processing center j to the incineration and landfill center m; X_{lm} is the quantity of non-remanufactured products transported from the disassembling center l to the incineration and landfill center m, where X_{ml_2} from traditional recycling channel, X_{ml_1} from the online recycling channel.

3.2. Model

According to the structure and symbol description of remanufacturing reverse logistics network for double-channel collection inspection, the following model is obtained.

The objective function as equation (1):

$$\begin{aligned} \min\ Z = &\sum_{k\in K}\sum_{i\in I} X_{ki}C_{ki}D_{ki} + \sum_{i\in I}\sum_{l\in L} X_{il}C_{il}D_{il} + \\ &\sum_{l\in L}\sum_{h\in H} X_{lh}C_{lh}D_{lh} + \sum_{i\in I}\sum_{m\in M} X_{im}C_{im}D_{im} + \sum_{k\in K}\sum_{j\in J} X_{kj}C_{kj}D_{kj} + \\ &\sum_{j\in J}\sum_{m\in M} X_{jm}C_{jm}D_{jm} + \sum_{j\in J}\sum_{l\in L} X_{jl}C_{jl}D_{jl} + \sum_{l\in L}\sum_{m\in M} X_{lm}C_{lm}D_{lm} \end{aligned} \tag{1}$$

Constraints on remanufacturing factory h as follows:

$$X_{lh} = X_{hl_1} + X_{hl_2} \quad \forall h\epsilon H \ \ \forall l_1,l_2\epsilon L \tag{2}$$

$$\sum_{l\in L} X_{lh} \le MP_h \qquad \forall h\in H \tag{3}$$

Equation (2) indicates that the total amount of the disassembling center transported to the remanufacturing factory is equal to the quantity of the disassembling center transported to the remanufacturing factory from the online and the quantity of the disassembling center transported to the remanufacturing factory from the offline; Equation (3) indicates that the transportation route from the disassembling center to the remanufacturing factory shall not be greater than the maximum remanufacturing capability of the remanufacturing factory.

Constraints on used product market k as follows:

$$X_k = \sum_{j\in J} X_{kj} + \sum_{i\in I} X_{ki} \qquad \forall k\in K \tag{4}$$

$$\sum_{j\in J} X_{kj} = \lambda X_k \qquad \forall k\in K \tag{5}$$

$$\sum_{i\in I} X_{ki} = (1-\lambda)X_k \qquad \forall k\in K \tag{6}$$

Equation (4) indicates that the total quantity of used products to be treated is equal to the sum of the quantity of used products to be treated in online channels and offline channels; Equations (5) and (6) indicate the proportion of used products to be treated in online channel and offline channel.

Constraints on disassembling center l as follows:

$$X_l = \sum_{i\in I} X_{il} + \sum_{j\in J} X_{jl} \quad \forall l \in L \tag{7}$$

$$X_l = \sum_{h\in H} X_{lh} + \sum_{m\in M} X_{lm} \quad \forall l \in L \tag{8}$$

$$\sum_{h\in H} X_{l_1 h} = \delta_i \sum_{i\in I} X_i \gamma_i (1-\beta_i) \quad \forall l_1 \in L \tag{9}$$

$$\sum_{h\in H} X_{l_2 h} = \delta_j \sum_{j\in J} X_j \gamma_j (1-\beta_j) \quad \forall l_2 \in L \tag{10}$$

$$X_l \leq MP_l, \forall l \epsilon L \tag{11}$$

$$\sum_{m\in M} X_{l_1 m} = \sum_{i\in I} X_i (1-\gamma_i)\alpha_i + (1-\delta_i)\sum_{i\in I} X_i \gamma_i (1-\beta_i) \quad \forall l_1 \in L \tag{12}$$

$$\sum_{m\in M} X_{l_2 m} = \sum_{j\in J} X_j (1-\gamma_j)\alpha_j + (1-\delta_j)\sum_{j\in J} X_j \gamma_j (1-\beta_j) \quad \forall l_2 \in L \tag{13}$$

Equation (7) the quantity of used products accepted by the disassembling center is equal to the sum of the used products sent to the disassembling center by the offline recycler and the online recycling and processing center; Equation (8) indicates that the sum of the remanufactured products transported by the disassembling center to the remanufacturing factory and the used products transported to the incineration and landfill center is equal to the number of remanufacturable products received by the disassembling center; Equation (9) indicates that the number of remanufactured products transported to the remanufacturing factory through the offline channel is equal to the proportion of the disassembled used products in the offline channel to the remanufacturing factory multiplied by the number of used products that can be truly remanufactured under the inspection error rate of the offline recycler; Equation (10) indicates that the quantity of the disassembled used products in the online channel sent to the remanufacturing factory is equal to the proportion of the disassembled used products in the online channel sent to the remanufacturing factory multiplied by the inspection error rate of the online recycling and processing center, and the quantity of the used products that can be truly remanufactured; Equation (11) indicates that the maximum quantity of used products accepted by the disassembling center cannot exceed the maximum processing capacity of the disassembling center; Equation (12) indicates that the quantity of used products transported from the disassembling center to the incineration and landfill center in the offline channel is equal to the sum of the quantity of non-disassembled used products erroneously detected as disassembled used products and the quantity of non-disassembled used products after passing through the disassembling center; Equation (13) indicates that the quantity of used products transported from the disassembling center to the incineration and landfill center in the online channel is equal to the sum of the quantity of non-disassembled used products that are erroneously detected as disassembled used products and the quantity that cannot be disassembled after passing through the disassembling center.

Constraints on the online recycling and processing center j as follows:

$$\sum_{l\in L} X_{jl} = [(1-\beta_j)\gamma_j + \alpha_j (1-\gamma_j)] X_j \quad \forall j \in J \tag{14}$$

$$\sum_{m\in M} X_{jm} = [\beta_j\gamma_j + (1-\alpha_j)(1-\gamma_j)]X_j \quad \forall j \in J \tag{15}$$

$$\sum_{k\in K} X_{kj} \le MP_j \quad \forall j \in J \tag{16}$$

$$\sum_{k\in K} X_{kj} = X_j \tag{17}$$

Equation (14) indicates that the total quantity of remanufacturable products transported by the online recycling and processing centers to all disassembly centers is equal to the quantity of remanufacturable products after testing; Formula (15) indicates that the quantity of non-remanufactured products transported by the online recycling and processing center to all incineration and landfill centers is equal to the quantity of non-remanufacturable products after testing; Equation (16) indicates that the quantity of used products transported from the consumption area to the online recycling and processing center cannot exceed the maximum remanufacturing capability of the offline recycler; Equation (17) indicates that the total quantity of used products in the online recycling and processing center is equal to the sum of the quantity of all used product markets transported to the online recycling and processing center.

Constraints on offline recycler i as follows:

$$\sum_{k\in K} X_{ki} = X_i \quad \forall i\in I \tag{18}$$

$$\sum_{l\in L} X_{il} = [(1-\beta_i)\gamma_i X_{ki} + \alpha_i(1-\gamma_i)]X_i \quad \forall i \in I \tag{19}$$

$$\sum_{m\in M} X_{im} = [\beta_i\gamma_i X_{ki} + (1-\alpha_i)(1-\gamma_i)]X_i \quad \forall i \in I \tag{20}$$

$$\sum_{k\in K} X_{ki} \le MP_i \quad \forall i \in I \tag{21}$$

Equation (18) indicates that the total quantity of used products detected by offline recyclers is equal to the sum of the quantity of all consumption areas transported to offline recyclers; Formula (19) represents the quantity of products in process that can be recycled offline and sent to all disassembly centers, which is greater than the total quantity of products that can be recycled after passing the inspection; Formula (20) indicates that the number of non-remanufactured products transported by offline recyclers to all incineration and landfill centers is equal to the number of non-remanufactured products after testing; Equation (21) represents the quantity of used products sent from the consumption area to the offline recyclers, which cannot be greater than the maximum inspection capacity of all offline recyclers.

4. Numerical Example

4.1. Related Parameter Settings

In the model, it is assumed that there are 4 consumption areas, 3 offline recyclers, 3 online recycling departments, 3 disassembling centers, 2 remanufacturing factories and 1 incineration and landfill center.

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Relevant parameter settings(the unit of used products is pieces, and the unit of transportation cost is yuan): there are 16000 used products in 4 used product market(consumption area); The maximum remanufacturing capability of the offline recycler is 5700, the maximum remanufacturing capability of the online recycling and processing center is 6000, the maximum disassembling capability of the disassembling center is 5000, and the maximum remanufacturing capability of the remanufacturing factory is 10000; The unit transportation cost from the used product market to the offline recycler is assigned as 0.4; The unit transportation cost from the offline recycler to the disassembling center is assigned as 0.3; The unit transportation cost from the disassembling center to the remanufacturing factory is assigned as 0.4; The unit transportation cost from the used product market to the online recycling and processing center is assigned as 0.4; The unit transportation cost from the online recycling and processing center to the disassembling center is assigned as 0.5; The unit transportation cost from the offline recycler to the incineration and landfill center is assigned as 0.4; The unit transportation cost from the online recovery and treatment department to the incineration and landfill center is assigned as 0.2; The unit transportation cost from the disassembly center to the incineration landfill center is 0.7; The inspection error rate of offline recyclers is 0.3; The inspection error rate of the online recycling department is 0.2. The distance (unit: km) is set as follows: the distances from the consumption area(K_1-K_4)to the offline recycler(I_1-I_3) are 370, 96, 145;137, 248, 148;200, 262, 187;80, 145, 139. The distances from the consumption area(K_1-K_4)to the online recycling department(J_1-J_3) are 348, 260, 138;145, 249, 156;139, 158, 260; 158, 176, 138. The distances from offline recyclers(I_1-I_3)to dismantling centers(L_1-L_3) are 235, 160, 140;140, 86, 132;328, 156 , 245. The distances from online recycling and processing departments(J_1-J_3)to dismantling centers(L_1-L_3) are 82, 118, 256;95, 113, 477;80, 120, 105. The distances from dismantling centers(L_1-L_3)to remanufacturing plants(H_1-H_2) are 125, 88;120, 71;98, 125. The distances from the incineration landfill Center to the offline recyclers(I_1-I_3) are 198, 270 and 96, and the distances to the online recycling and treatment departments(J_1-J_3) are 322, 226 and 274, and the distances to the remanufacturing plants(H_1-H_2) are 390, 118 and 199.

4.2. Traffic Scheme

Table 1. optimization results of dual channel reverse logistics distribution network $\boldsymbol{\lambda}=\mathbf{50}\%$

transportation route		transportation route	
from used product market to offline recycler	$K_1\to I_2$ (2000)	from online recycling and processing center to disassembling center	$J_1\to L_1$ (2280)
	$K_2\to I_3$ (2000)		$J_2\to L_2$ (440)
	$K_3\to I_3$ (2000)		$J_3\to L_1$ (2720)
	$K_4\to I_1$ (2000)	from disassembling c enter to incineration and landfill center	$L_2\to M_1$ (1944)
from used product market to online recycling and processing center	$K_1\to J_3$ (2000)	from online recycling and processing center to incineration and landfill center	$J_1\to M_1$ (840)
	$K_2\to J_1$ (2000)		$J_2\to M_1$ (840)
	$K_3\to J_1$ (1353)		$J_3\to M_1$ (1680)
	$K_3\to J_2$ (647)	from offline recycler to incineration and landfill Center	$I_1\to M_1$ (1073)
	$K_4\to J_3$ (2000)		$I_2\to M_1$ (207)
from offline recycler to disassembling center	$I_1\to L_2$ (1080)		$I_3\to M_1$ (1280)
	$I_2\to L_2$ (1160)	from disassembling center to remanufacturing factory	$L_1\to H_2$ (5000)
			$L_2\to H_2$ (3056)
	$I_3\to L_2$ (2320)		$L_3\to H_1$ (80)

The initial state is when online channel and traditional channel obtain the same market share, that is $\lambda = 50\%$.According to the above parameter settings, LINGO 11.0 is used to solve the global optimization of the above model, and the minimum cost is 2079423 yuan. See Table 1 for the optimized transportation route. The letters in the table are the optimized routes, the subscripts of the letters are the selection of nodes, and the numbers in brackets are the corresponding distribution volumes.

5. Conclusion

In this paper, by constructing the optimization model of remanufacturing reverse logistics distribution network with dual channel recovery inspection, and using LINGO 11.0 for numerical calculation, the optimized transportation scheme of the logistics distribution network is given, which provides a reference for similar problems in the logistics distribution scheme for enterprises, and can make the logistics distribution network better applied to the reality.

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