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Reverse Logistics Network Optimization of Express Packaging Boxes in Colleges and Universities Based on The Background of Green Logistics

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ABSTRACT

Given the high volume of express delivery in universities and the inadequate recycling system for express packaging boxes, this paper studies a reverse logistics network for express packaging boxes based on green logistics. Green logistics mainly refers to the sustainable development model of express delivery aimed at reducing resource consumption and environmental pollution during the logistics process. This paper constructs a reverse logistics optimization model for express packaging boxes, aiming to minimize the total cost of reverse logistics by recycling express packaging to reduce environmental pollution while maximizing social benefits. At the same time, triangular fuzzy numbers were used to define the uncertainty parameters in the text, and feasibility theory was used to equivalently transform the constraint conditions of the model by setting parameters such as confidence levels. The experimental results indicate that the model can realistically simulate the decision-making process of reverse logistics network for university express delivery packaging boxes, and is feasible; The Lingo program can effectively assist in finding the best solution.

KEYWORDS

Reverse logistics; Green Logistics; Express box

1. INTRODUCTION

With the rapid development of China's e-commerce, China's express delivery industry has also maintained a rapid development. Express delivery not only brings convenience to our life, but also brings us many problems, the most serious of which is environmental pollution and waste of resources. People's Daily has pointed out that there are serious problems such as waste of resources and pollution in China's express packaging, urging the transformation and development of the express industry, and sounding the alarm for the seriously polluted express industry. The recycling of express packaging can not only effectively reduce environmental pollution and waste of resources, but also increase jobs and promote employment to bring benefits to society, which is of great significance for promoting the sustainable development of green logistics and promoting economic growth.

In recent years, under the guidance of the concept of green development and the green and low-carbon development policies successively introduced, China's green logistics has shown a rapid development trend, and is transforming into a modern logistics with low pollution, low consumption, low emissions, high efficiency, high efficiency and high efficiency. There are more and more researches on the recycling of express packaging boxes. At present, the research on reverse logistics network of express packaging boxes includes the research on the recycling mode and recycling strategy, and part of the research is conducted by building a mathematical model. For example, Alshamsi et al. [1] established a complex reverse logistics network system, including the decision on the location of network facilities, the design of the capacity of reverse logistics center and remanufacturing equipment, and the selection of transportation modes. Ma Zujun et al. [2] analyzed the remanufacturing logistics network system and proposed a remanufacturing logistics optimization model, which can minimize the investment and operating costs of remanufacturing logistics equipment and the transportation costs between facilities. Cheng Bo et al. [3] established a three-level reverse logistics network model, including garbage recycling plant, college recycling site, dormitory building and Cainiao Courier station, aiming at the problem of packaging recycling in colleges and universities, and used the gravity center method to make site selection decisions. Li Shanshan et al. [4] built a reverse logistics network consisting of five-level network nodes of residential sites, recycling centers, processing centers, remanufacturing centers and incineration and landfill centers, and used triangular fuzzy numbers to solve the problem of uncertain recycling amount.

However, most of the above studies did not consider the uncertainty factors of packaging supply and demand, recycling quantity, recycling time and recycling quality. In addition, the research on reverse logistics network of express packaging is mostly a single goal and only considers the cost aspect, lacking the research on environmental impact. Therefore, the reverse logistics network of express packaging box under the background of green logistics proposed in this paper includes the following characteristics: 1. Consider the uncertainty of the recycling amount of express packaging boxes; 2. Considering the minimum comprehensive cost of reverse logistics, the impact of the network on the environment is also considered. To sum up, this paper will establish the reverse logistics network optimization model, use the triangular fuzzy number to process the uncertain parameters, and use lingo to solve the model.

2. MODEL CONSTRUCTION

2.1. Problem Description and Model Assumptions

In this paper, the reverse logistics network of college express packaging boxes is constructed from four levels, including universities, recycling transfer stations, remanufacturing centers and garbage dumps, when the recycling quantity of college express packaging boxes is uncertain. In the reverse logistics network, the universities will be unified express packaging boxes to the recycling transfer station, recycling transfer station for express packaging boxes for simple processing will be these express packaging boxes can be remanufactured and directly destroyed processing. Then the recycling transfer station will be able to remanufacture the express packaging box transported to the remanufacturing center for remanufacturing processing and then re-enter the market for customers to use, while the need to destroy the express packaging box is directly transported to the garbage dump for unified destruction treatment.

Relevant assumptions of the model are as follows:

1) The number of express packages in each university is independent of each other, and can be expressed by triangular fuzzy numbers;

2) The geographical location and number of alternative recycling transfer stations and remanufacturing centers are known;

3) In terms of costs, only transportation costs, fixed construction costs of facilities and unit processing costs are considered, and time costs are not considered;

4) The maximum processing capacity of each network node is known;

5) Recycling transfer stations and remanufacturing centers and garbage disposal units are known to have an environmental impact, and transportation units are known to have an environmental impact.

2.2. Symbol Description

2.2.1. Node collection

K Set of colleges and universities, a certain college is represented by k;

J Collection of recycling transfer stations, a recycling transfer station is represented by j;

H Set of remanufacturing centers, a remanufacturing center is represented by h;

I Collection of garbage sites, a garbage site is represented by i;

2.2.2. Fuzzy parameters

m The rate of recyclability for remanufacturing;

$\tilde{d}_k$ The ambiguous quantity of express packages recycled by colleges and universities;

p_j The unit processing cost of recycling transfer station j;

q_j The maximum processing capacity of the recycling transfer station j;

f_j The fixed cost of constructing the recycling transfer station j;

p_h Unit remanufacturing cost of remanufacturing center h;

q_h The maximum processing capacity of the remanufacturing center h;

f_h Fixed costs for the construction of remanufacturing center h;

p_i Unit disposal cost of dump i;

q_i The maximum processing capacity of dump i;

t_{kj} The unit transportation cost for the university point to the recycling transfer station j;

t_{jh} Unit transportation cost for recycling transfer station j to remanufacturing center h;

t_{ji} Unit transport costs for recycling transfer station j to dump site i;

e_{kj} Carbon emissions of unit express packaging recycling boxes shipped to recycling transfer station j at university points;

e_{jh} Carbon emissions per unit of express package recycling box for recycling transfer station j to remanufacturing center h;

e_{ji} Carbon emissions per unit of express package recycling boxes shipped to dump i for recycling transfer station j;

e_j The carbon emissions of the express packaging recycling box of the processing unit of the recycling transfer station j;

e_h Remanufacturing Center h handles carbon emissions per unit of express packaging recycling box;

e_i The carbon emissions of garbage dump i processing unit express packaging recycling box;

2.2.3. Decision variables

y_j Variable 0 to 1, indicating whether the alternative recycling transfer station j is selected,0 indicating that it is not selected,1 indicating that it is selected;

y_h Variable 0 to 1 indicates whether the alternative remanufacturing center h is selected,0 indicates that it is not selected, and 1 indicates that it is selected.

y_i Variable 0 to 1: indicates whether the alternative dump site i is selected,0 indicates that it is not selected, and 1 indicates that it is selected.

x_{kj} The number of express packaging boxes delivered by University k to recycling transfer station j;

x_{jh} The number of delivery boxes delivered to remanufacturing Center h via recycling transfer station j

x_{ji} The number of packages delivered to dump i via recycling transfer station j;

2.3. Mathematical Model

In this paper, an optimization model is established with the aim of minimizing the total operating cost of reverse logistics network, and the impact of logistics network on social benefits is considered.

Objective function 1:

$$\begin{aligned} \min = &\sum_j f_j * y_j + \sum_h f_h * y_h + \sum_k \sum_j x_{kj} * t_{kj} + \sum_j \sum_h x_{jh} * t_{jh} + \sum_j \sum_i x_{ji} * t_{ji} + \sum_k \sum_j x_{kj} * p_j \\ &+ \sum_j \sum_h x_{jh} * p_h + \sum_j \sum_i x_{ji} * p_i \end{aligned} \tag{1}$$

Objective function 2:

$$\begin{aligned} \max = &\sum_k \sum_j x_{kj} * e_{kj} + \sum_j \sum_h x_{jh} * e_{jh} + \sum_j \sum_i x_{ji} * e_{ji} + \sum_k \sum_j x_{kj} * e_j + \sum_j \sum_h x_{jh} * e_h + \\ &\sum_j \sum_i x_{ji} * e_i \end{aligned} \tag{2}$$

St.

$$\sum_j x_{kj} \le \tilde{d}_k \qquad \forall k \tag{3}$$

$$\sum_h x_{jh} = m * \sum_k x_{kj} \quad \forall j \tag{4}$$

$$\sum_k x_{kj} = \sum_h x_{jh} + \sum_i x_{ji} \qquad \forall j \tag{5}$$

$$x_{kj}, x_{jh}, x_{ji} \ge 0 \qquad \forall k, j, h, i \tag{6}$$

$$y_j, y_h, y_i = 0 or 1 \quad \forall j, h, i \tag{7}$$

$$\sum_k x_{kj} \le q_j * y_j \qquad \forall j \tag{8}$$

$$\sum_h x_{jh} \le q_h * y_h \qquad \forall h \tag{9}$$

$$\sum_i x_{ji} \le q_i * y_i \qquad \forall i \tag{10}$$

Formula interpretation: (1) Objective function 1 represents the minimization of network costs, including construction costs, transportation costs and operating costs; (2) Objective function 2 represents the maximization of social benefits; (3) ~ (5) Constrain the traffic of each network node; (6) ~ (7) Limits the value range of decision variables; (8) ~ (10) Limit the maximum processing capacity of recycling transfer station, remanufacturing center and garbage dump respectively.

2.4. Model Optimization

Since the constructed model contains fuzzy parameters, the feasible optimal solution cannot be obtained by directly solving the above model, resulting in the model being divorced from reality. Therefore, deterministic methods cannot be adopted to solve the objective function, and it needs to be fuzzy processing. On the basis of existing literature research and practical problems, the credibility theory is introduced, confidence level parameters are set, all uncertain parameters are transformed into triangular fuzzy numbers, and the original uncertain problems are transformed into deterministic equivalence class approximate solutions. Since the constraint condition (3) contains fuzzy parameters, the fuzzy constraint condition is transformed into a fuzzy chance constraint model.

$$pos\left\{\sum_j x_{kj} \le \tilde{d}_k\right\} \ge \alpha \tag{11}$$

The chance constraint indicates the probability of being satisfied if the confidence level is guaranteed to be at least at α.

The relevant lemma of chance constraints is described below.

Lemma 1 Let the trigonometric fuzzy function A be (la, ma, pa), then for a given confidence level $\alpha(0 \le \alpha \le 1)$, if and only if $(1-\alpha)la + \alpha * ma \le u \le (1-\alpha)pa + \alpha * ma$, there is $pos\{u \le A\} \ge \alpha$.

According to lemma 1, the constraint condition (3) can be transformed into:

$$\sum_j x_{kj} \ge (1-\alpha)la + \alpha * ma \tag{12}$$

$$\sum_j x_{kj} \le (1-\alpha)pa + \alpha * ma \tag{13}$$

LP-metric method is used to process objective functions: multiple objective functions are converted into single objective functions for solving. First, LINGO software is used to solve each objective function to obtain its ideal value Z_1^*, Z_2^*, where $Z_1^*=3569662$, $Z_2^*=25731.08$. r_1, r_2 is the weight given by the decision-maker and $r_1, r_2 \in [0,1]$, here we assume $r_1=0.6$, $r_2=0.4$ according to the expert's suggestion. The above multiple objective functions can be converted into the following single objective function form:

$$\min z = r_1 \frac{z_1 - z_1^*}{z_1^*} + r_2 \frac{z_2 - z_2^*}{z_2^*} \tag{14}$$

Using the triangular fuzzy number and LP-metric method mentioned above, the multi-objective function model can be transformed into a clear equivalent form of single objective function, that is, the objective function is equation (14), and the constraint conditions are equation (4) ~ (10) and equation (12) ~ (13).

3. EXAMPLE SOLUTION AND ANALYSIS

3.1. Data Description

In order to verify the feasibility of the model, a university in a city of Henan Province is taken as an example to verify the model. There are 6 universities, 5 alternative recycling transfer stations, 4 alternative remanufacturing centers, and 1 alternative garbage dump. The remanufacturing ratio of express packages is 0.7, the unit processing cost of garbage plant is 8 yuan, and the maximum processing capacity is 10,000 pieces. Carbon emissions per unit of express packaging recycling boxes are 0.24 kg. Other parameter assignment data (unit: pieces, yuan, kg) are shown in the following table:

Table 1. The fuzzy quantity of express packaging boxes in each university and the quantity after fuzzy processing

Colleges and universities k	$\tilde{d}_k$	α
		(0.9,0.9,0.9)
k=1	(4500,4700,4900)	4680
k=2	(3800,4000,4200)	3980
k=3	(4000,4200,4400)	4180
k=4	(4300,4500,4700)	4480
k=5	(4100,4300,4500)	4280
k=6	(4400,4600,4800)	4580

Table 2. Unit processing cost, fixed cost, maximum processing capacity and carbon emission of each recycling transfer station

	p_j	f_j	q_j	e_j
j=1	23	200000	5000	0.26
j=2	20	220000	5500	0.28
j=3	25	240000	5200	0.3
j=4	30	245000	5400	0.32
j=5	27	215000	5600	0.34

Table 3. Unit processing cost, fixed cost, maximum processing capacity and carbon emission of each remanufacturing center

	p_h	f_h	q_h	e_h
h=1	14	25000	4800	0.24
h=2	17	245000	5100	0.26
h=3	16	26000	5400	0.28
h=4	15	265000	5000	0.3

Table 4. The unit transportation cost and unit carbon emission of recycling transfer station to garbage dump

t_{ji}/e_{ji}					
	j=1	j=2	j=3	j=4	j=5
i=1	14/0.28	16/0.32	18/0.34	19/0.36	20/0.38

Table 5. The unit transportation cost and unit carbon emission of university point k transported to recycling transfer station j

t_{kj}/e_{kj}						
	k=1	k=2	k=3	k=4	k=5	k=6
j=1	18/0.34	16/0.32	22/0.38	21/0.37	25/0.4	22/0.38
j=2	23/0.39	12/0.22	18/0.34	26/0.4	16/0.32	17/0.33
j=3	19/0.34	16/0.32	17/0.33	18/0.34	20/0.35	24/0.39
j=4	21/0.37	19/0.34	23/0.38	22/0.38	17/0.33	23/0.38
j=5	16/0.32	20/0.35	20/0.35	24/0.39	21/0.37	25/0.4

Table 6. The unit transportation cost and unit carbon emission of recycling transfer station h to remanufacturing center j

t_{jh}/e_{jh}					
	j=1	j=2	j=3	j=4	j=5
h=1	20/0.35	17/0.33	16/0.32	24/0.39	21/0.34
h=2	16/0.32	15/0.31	12/0.22	16/0.28	22/0.35
h=3	15/0.24	19/0.34	23/0.34	23/0.38	17/0.29
h=4	18/0.34	21/0.37	20/0.32	19/0.33	18/0.3

3.2. Model Solving

The model is solved by using LINGO software, which is specially used to solve optimization problems. The software is by the United States LINGO System Inc. (Lingo System Inc.) launched, can be used to solve nonlinear programming, can also be used to solve some linear and nonlinear equations, etc., the function is very powerful, is the best choice for solving optimization models.

LINGO11.0 was used to solve the calculation example, and the results showed that the optimal value of the objective function z_1=3573442, z_2=25793.6, and the optimal value of other decision variables were shown in the following table:

Table 7. The optimal value of each decision variable of the objective function

Optimal value of the objective function					
y_j	$y_1=1$	$y_2=1$	$y_3=1$	$y_4=1$	$y_5=1$
y_h	$y_1=1$	$y_2=1$	$y_3=1$	$y_4=1$	
y_i	$y_1=1$				
x_{kj}	$x_{11}=2540$	$x_{13}=720$	x_{15} 1420	$x_{22}=3980$	$x_{35}=4180$
x_{kj}	$x_{43}=4480$	$x_{54}=4280$	$x_{61}=2460$	$x_{62}=1520$	$x_{64}=600$
x_{jh}	$x_{13}=3500$	$x_{21}=3850$	$x_{31}=950$	$x_{32}=2690$	$x_{42}=2410$
x_{jh}	$x_{44}=1006$	$x_{35}=1900$	$x_{54}=2020$		
x_{ji}	$x_{11}=1500$	$x_{21}=1650$	$x_{31}=1560$	$x_{41}=1464$	$x_{51}=1680$

3.3. Result Analysis

When the remanufacturing ratio m=0.7 and the confidence level α =0.9, 5 recycling transfer stations, 4 remanufacturing centers and 1 garbage dump are selected. There are 3 paths from college 1 to the recycling transfer station, 3 paths from college 6 to the recycling transfer station, and 1 path from other colleges to the recycling transfer station. There are 2 paths from recycling transfer stations 3,4,5 to the remanufacturing center, and 1 path from other recycling transfer stations to the remanufacturing center. Each recycling transfer station has one path to the dump. Through the analysis of the above examples, it is proved that the constructed objective function is effective when the confidence level is 0.9, which can solve the traffic distribution problem among the facilities of the reverse logistics network of college express packaging boxes.

4. SUMMARY

This paper studies the optimization of reverse logistics network of college express packaging boxes, recycling and remanufacturing express packaging, and centralized destruction of unreusable express packaging, which conforms to the concept of green logistics and is conducive to reducing environmental pollution and waste of resources and promoting sustainable development. After considering the uncertainty of the quantity of package box recycling, an integer nonlinear programming model is established to minimize the cost and the minimum carbon emission of the whole logistics network system. By introducing the feasibility theory, using the triangular fuzzy number to transform the uncertain parameters into clear numbers, and using the LP-metric method to process the objective function, the multi-objective function is transformed into a single objective function, which reduces the complexity of the problem. The results show that the model can reduce the environmental pollution while recycling the package box at a lower cost, which is very meaningful. However, since reverse logistics involves many factors, it will also be affected by other factors, such as the discard rate between network nodes, which will also be the next research direction.

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