Construction and Optimization of Recycling Logistics Network for Construction Waste

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Abstract. Project construction is one of the most important economic activities. How to disposal construction waste is an urgent issue in the management of city. The traditional method is simple landfill, not only occupy the land, causing environmental pollution, but also waste a lot of resources which can be rational recycling. In this paper, considering the establishment of a reasonable reverse logistics network for construction waste to achieve the recycling, minimize the total cost such as network facilities investment, operation cost, transportation cost and other related costs.

Introduction

Construction waste refers to dregs, concrete block, a small amount of steel, wood and other wastes generated in the process of construction, is a kind of recyclable resources [1-2]. The implementation of recycling requires appropriate logistics network support, including the number and position of facilities such as recycling center, detection processing center, distribution center, building materials suppliers etc. Rational design of recycling network, determines the effectiveness of waste recycling. This paper considers construction of reverse logistics based on the existing building materials logistics network, and through an example to verify the feasibility and effectiveness of the model.

Description of the Problem

Suppose there is a construction waste reverse network, including waste recycling center, detection processing center, regenerative machining center three kinds of logistics facilities. After recycling center classification, construction waste inspected qualified in the detection processing center can directly be shipped to distribution center to sales; waste detection renewable can be shipped to regenerative machining center for further processing; unqualified will be waste disposal [3][4]. Flow chart of reverse recycling network as shown in Fig. 1.

In the construction of waste reverse logistics network based on existing building materials logistics network, the original building materials suppliers (or distribution center) can be used as regenerative machining center (or recycling center), or you can create some new.
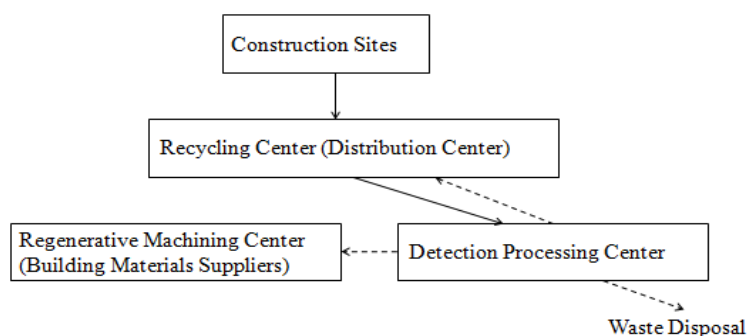

Fig.1. Flow chart of reverse recycling network

Model Establishment

The Model Assumptions.(1)The cost of transportation and traffic volume between facilities are a linear relationship, correlation processing costs about recycling center, detection processing center and regenerative machining center are a linear function of the amount of processing.

(2)Waste recycling, the facilities processing capacity, infrastructure investment costs, unit operation variable costs, recycling classification and detection processing costs, as well as transportation cost between facilities and the disposal cost is determined.

(3)Because the operation variable cost relates to the facilities, so introduce an index of θ（$0<\theta\leq1$）, to consider the scale economy of facilities.

(4)Construction waste inspection qualified can directly be shipped to distribution center to sales; waste detection renewable can be shipped to regenerative Machining center to process; unqualified will be waste disposal, waste disposal rate is μ.

(5)Considering material loss during transportation, thereby introduce the material loss factor α, pay the cost per unit of material loss is indicated by Cc.

(6)The recycling center and detection processing center exists absorption rate of construction waste, respectively represented by the factor r_1 and r_2.

(7)Alternative address about recycling center, detection processing center or regenerative machining center is known.

(8)The new regenerative machining center or expansion building materials suppliers are willing to accept the recycled materials as much as possible.

The Mathematical Model. *Model Symbol.* H represents a collection of construction sites, h in H; I represents a collection of recycling center (or expansion distribution center) , i in I; J represents a collection of detection processing center, j in J; K represents a collection of regenerative machining center (or expansion building materials suppliers), k in K.

The Parameters In The Model. A_h represents the recycling amount of construction waste; MAX-U_i represents the maximum recycling amount of new recycling center or expansion distribution center i; MAX-V_j represents the maximum treatment capacity of new detection processing center j; MIN-Wk represents the minimum processing ability on construction waste of new regenerative machining center or extension of building materials supplier k; TC_{hi} represents the unit cost of transportation from construction sites h to recycling center i; TC_{ij} represents the unit cost of transportation from i to detection processing center j; TC_{jk} represents the unit cost of transportation from j to regenerative machining center k; C_i represents the infrastructure investment costs of recycling center i; C_j represents the infrastructure investment costs of detection processing center j; C_k represents the infrastructure investment costs of regenerative machining center k; OC_i represents the unit processing costs of recycling center i; OC_j represents the unit testing costs of detection processing center j; LC_j represents the unit disposal costs of detection processing center j; OC_k represents the unit cost of further processing of detection processing center j; V_i represents the Coefficient of unit cost changes of recycling center i; V_j represents the Coefficient of unit cost changes of detection processing center j; V_k represents the Coefficient of unit cost changes of regenerative machining center k; C_c represents per unit material loss for the cost; N_1,N_2,N_3 represent the maximum number of establishing recycling center, detection processing center and regenerative machining center respectively; r_1 represents the construction waste absorption rate of recycling center; r_2 represents the construction waste absorption rate of detection processing center.

The Decision Variables. M_{hi} represents the number of waste from construction sites h to recycling center i; X_{ij} represents the number of waste from recycling center i to detection processing center j; Y_{jk} represents the number of waste from detection processing center j to regenerative machining center k; Z_{ji} represents the number of waste from detection processing center j to distribution center i; P_i represents the turnover of construction waste in the new recycling center i or expansion distribution center i; Q_j represents the turnover of construction waste in the new detection processing center j; R_k represents the turnover of construction waste in

the new regenerative machining center k or expansion building material suppliers k; D_i is a 0~1 variable, indicating whether the establishment of a recycling center in the i, is 1, otherwise 0; E_j is a 0~1 variable, indicating whether the establishment of a detection processing center in the j, is 1, otherwise 0; F_k is a 0~1 variable, indicating whether the establishment of a regenerative machining center in the k, is 1, otherwise 0;

The Objective Function.

$$\min f = \sum_{h \in H}\sum_{i \in I} TC_{hi}M_{hi} + \sum_{i \in I}\sum_{j \in J} TC_{ij}X_{ij} + \sum_{j \in J}\sum_{k \in K} TC_{jk}Y_{jk} + \sum_{j \in J}\sum_{i \in I} TC_{ji}Z_{ji} + \sum_{i \in I} OC_iP_i + \sum_{j \in J} OC_jQ_j + \sum_{k \in K} OC_kR_k + \sum_{j \in J} \mu Q_j LC_j + \tag{1}$$

$$\sum_{i \in I} \alpha P_iC_c + \sum_{j \in J} \alpha Q_jC_c + \sum_{i \in I} V_iP_i^\theta + \sum_{j \in J} V_jQ_j^\theta + \sum_{k \in K} V_kR_k^\theta + \sum_{i \in I} C_iD_i + \sum_{j \in J} C_jE_j + \sum_{k \in K} C_kF_k$$

The Constraint Conditions.

$$\sum_{i \in I} M_{hi} = r_1(1-\alpha)A_h, h \in H \tag{2}$$

$$\sum_{j \in J} X_{ij} = r_2(1-\alpha)\sum_{i \in I} M_{hi}, h \in H \tag{3}$$

$$\sum_{j \in J} Y_{jk} + \sum_{j \in J} Z_{ji} = (1-\alpha)(1-\mu)\sum_{j \in J} X_{ij}, i \in I, k \in K \tag{4}$$

$$\sum_{i \in I} M_{hi} \le MAX - U_i, h \in H \tag{5}$$

$$\sum_{j \in J} X_{ij} \le MAX - V_j, i \in I \tag{6}$$

$$\sum_{k \in K} Y_{jk} \ge MIN - W_k, j \in J \tag{7}$$

$$\sum_{i \in I} M_{hi} = P_i, h \in H \tag{8}$$

$$\sum_{j \in J} X_{ij} = Q_j, i \in I \tag{9}$$

$$\sum_{k \in K} Y_{jk} = R_k, j \in J \tag{10}$$

$$\sum_{i \in I} D_i \le N_1 \tag{11}$$

$$\sum_{j \in J} E_j \le N_2 \tag{12}$$

$$\sum_{k \in K} F_k \le N_3 \tag{13}$$

$$M_{hi}, X_{ij}, Y_{jk}, Z_{ji} \ge 0, h \in H, i \in I, j \in J, k \in K \tag{14}$$

$$D_i, E_j, F_k = 0 \, or \, 1, i \in I, j \in J, k \in K \tag{15}$$

In the model, the objective function (1) expressed the minimum total cost of transportation cost between facilities, construction waste treatment cost, fixed investment cost, operation variable costs, waste disposal cost and material loss cost. Type (2) to type (4) is the flow balance constraints, type (5) to type (7) is the facilities processing capacity constraints, type (8) to type (10) represents the circulation and handling capacity of each node is equal, type (11) to type (13) is the new facilities quantitative restrictions. The above problem is a capacitated network location problem, whose model is a mixed integer programming model (MILP), can be solved by using the software Lingo.

Simulation Examples

There are 6 construction engineering buildings, 5 alternative locations of recycling center in a region, where I_1, I_2 can be considered to expand original distribution center; I_3, I_4, I_5 is a new candidate site; 3 alternative locations of detection processing center, J_1, J_2 and J_3; 4 alternatives of regenerative machining center in which K_1, K_2 construction material supplier, K_3, K_4 is a new candidate site. The material loss factor $\alpha=0.05$, the cost per unit of material loss $C_c=10$, absorption rate of recycling center $r_1=80\%$, absorption rate of detection processing center $r_2=60\%$, waste disposal rate $\mu=0.2$, index $\theta=0.6$. Other relevant data as Table 1~10 shown.

Using Lingo software to solve the above data, the results are shown in Fig.2. The minimum total cost is 626075; establish recycling center in the candidate I_1, I_2, I_5; detection processing center in J_2, J_3; regenerative machining center in the candidate K_1, K_2.

Table.1 The amount of construction waste recycling of construction sites

The amount of construction waste recycling	Construction sites					
	H_1	H_2	H_3	H_4	H_5	H_6
A_h	115	150	140	69	50	50

Table.2 The recycling amount of recycling center

Recycling amount	Recycling center				
	I_1	I_2	I_3	I_4	I_5
MAX-U_i	130	140	175	190	168

Table.3 The processing ability of detection processing center

Treatment capacity	Detection processing center		
	J_1	J_2	J_3
MAX-V_i	180	190	170

Table 4 The processing ability of regenerative machining center

Processing ability	Regenerative machining center			
	K_1	K_2	K_3	K_4
MIN-W_k	50	60	45	30

Table.5 The unit transport costs from construction sites to recycling center

Recycling center	Construction sites					
	H_1	H_2	H_3	H_4	H_5	H_6
I_1	5	10	8	12	20	9
I_2	10	5	6	4	32	16
I_3	18	12	24	8	6	15
I_4	6	16	11	14	12	8
I_5	30	25	20	14	16	6

Table.6 The unit transport costs from recycling center to detection processing center

Detection processing center	Recycling center				
	I_1	I_2	I_3	I_4	I_5
J_1	15	8	6	12	10
J_2	10	10	8	14	18
J_3	12	14	20	16	8

Table.7 The unit transport costs from detection processing center to regenerative machining center

Regenerative machining center	Detection processing center		
	J_1	J_2	J_3
K_1	16	12	20
K_2	8	14	9
K_3	20	14	8
K_4	4	10	14

Table.8 Other costs related to recycling center

Cost	Recycling center				
	I_1	I_2	I_3	I_4	I_5
C_i	12000	20000	120000	150000	100000
OC_i	6	8	10	5	10
V_i	18	20	11	12	16

Table.9 Other costs related to detection processing center

Cost	Detection processing center		
	J_1	J_2	J_3
C_i	320000	210000	240000
OC_i	5	6	8
V_i	15	10	20
LC_i	12	15	24

Table.10 Other costs related to regenerative machining center

Cost	Regenerative machining center			
	K_1	K_2	K_3	K_4
C_k	15000	12000	120000	150000
OC_k	20	15	8	6
V_k	12	15	7	10

```
Local optimal solution found.
   Objective value:                         626075.0
   Objective bound:                         626075.0
   Infeasibilities:                    0.1421085E-13
   Extended solver steps:                         26
   Total solver iterations:                     3031


                     Variable           Value
                          D1        1.000000
                          D2        1.000000
                          D3        0.000000
                          D4        0.000000
                          D5        1.000000
                          E1        0.000000
                          E2        1.000000
                          E3        1.000000
                          F1        1.000000
                          F2        1.000000
                          F3        0.000000
                          F4        0.000000
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Fig.2. The simulation calculation results

Conclusion

This paper constructed a reverse recycling network based on the original building materials logistics. The network relates to three facilities about recycling center, detection processing center and regenerative machining center, considered the fixed investment cost, variable operating costs, unit cost of processing and transport cost, proposed a mixed integer programming model (MILP), and given specific examples and simulation method, realized the goal of minimum total cost.

However, because the construction waste reverse logistics involves a wide range, complicated influence factors and has the characteristics of randomness, therefore, in the planning of the actual problem, besides considering the principle of the lowest cost, should also consider environmental factors and other special requirements, further research also can consider to solve the uncertainty problem of construction waste reverse recycling.

References

[1] Shuai Cao, Yanling Shi. Discussion on the status and recycling management of construction waste [J]. Resource Saving and Environmental Protection, 11 (2013) 53.

[2] Xiuyu Li. Construction waste "turning waste into treasure" [N]. Shenzhen Commercial Daily, 2014-4-7(A01).

[3] Xiang Du. Study of building solid waste reverse logistics based on circular economy [D]. Hubei: Wuhan Science and Technique University, Master degree thesis (2012).

[4] Jingru Li, Xuming Mi, Zhikun Ding, Zhenrong Lin. Investigation on Generation and Disposal of Construction Waste on Site [J]. Ecological Economy, 4 (2011) 105-108.

[5] Peng Song. Regeneration practice of construction waste[A]. The Tenth International Conference on Green and Energy-Efficient Building [C]. 2014.