THE RESEARCH OF PAPER REVERSE LOGISTIC NETWORK OPTIMIZATION ON THE LOW-CARBON ECONOMY

Wu Rongxu, Ru Yihong, Wu Shengna
Beijing Jiatong University, Beijing, China

Su Chang
Beijing Jiatong University, Beijing, China

Keywords: Low-carbon economy, Reverse logistics, Network optimization, Paper reverse, Carbon emission.

Abstract: As the contradiction between natural resources and economic development become more and more serious, people in the 21st century is facing a new revolution of the method of the economic development, with low fuel consumption, low recourse consumption, low gas emission, and low environmental pollution, low-carbon economy is a new choice for the future economic development. This paper firstly introduces the current study status of low-carbon economy and reverse logistics network, then by taking the paper reverse industry as an example, defines the mathematic relationship between reverse logistic network optimization with the help of the relationship between paper and tree, and finally demonstrate the feasibility in the combination of the low-carbon economy and reverse logistics network, making a model that maximizes the benefits and minimizes the carbon emission. This paper provides a valuable reference for the subsequent research.

1 CURRENT STATUS OF THE STUDY

As low-carbon economy is on the rise globally, many scholars made attribution to the study within related fields. Currently low-carbon economic researches have mainly focused on the macroscopic policy and transition of renewable energy resources. The research of reverse logistic network is also wide, most of which analyze from the theoretical view, including the mode, decisional problem and network construction of the reverse logistics to resolve the problem about location and transport routes.

2 APER REVERSE LOGISTICS NETWORK

Under the new social situation reverse logistics network planning should meet the higher demands, especially the paper recycling network which cost a large amount of waste the resource .This research has been carried out in the area of reverse logistics of the paper recycling industry. Paper reverse logistics network belongs to recycling reverse logistics. Our national waste paper recycling network is now inefficient. There are some cross exist among main body of every level in the network, and the waste paper recovery is fragmented and complex.

This article is based on the existing problems in the waste paper recycling system and the reverse network. Simplification of the network is on the table. The primary level is consists of scattered customers and trash treatment plants. The second level contains waste pretreatment plants waste recycling companies. The third includes the Second-handed market and Paper Mill. The network of three levels is as below：

Rongxu W., Yihong R., Shengna W. and Chang S..
THE RESEARCH OF PAPER REVERSE LOGISTIC NETWORK OPTIMIZATION ON THE LOW-CARBON ECONOMY.
DOI: 10.5220/0003604403360340
In *Proceedings of the 13th International Conference on Enterprise Information Systems* (BIS-2011), pages 336-340
ISBN: 978-989-8425-54-6

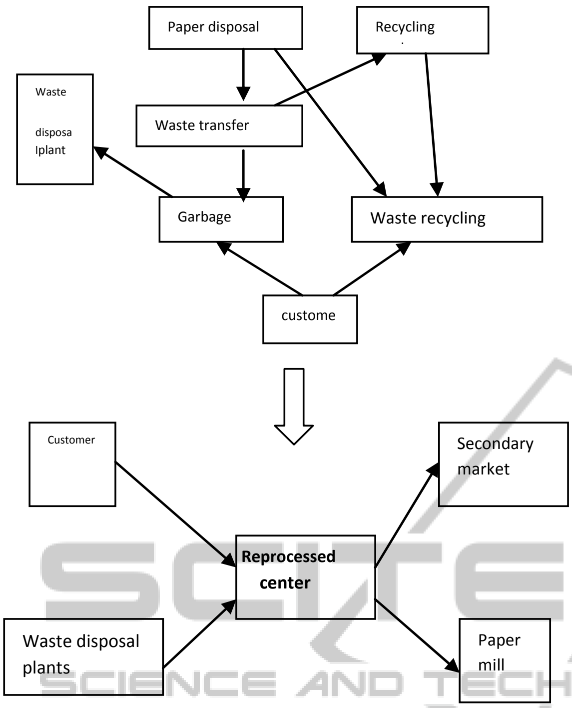

Figure 1: Paper reverse network.

The network set rules about specifications and responsibilities of each main body while more attention is distribute to the optimization of garbage recycling network. In this way, it achieves higher recycling rate and standard rules in waste recycling field.

3 FEASIBILITY ANALYSIS IN THE COMBINATION OF THE LOW-CARBON ECONOMY AND REVERSE LOGISTICS NETWORK

At present, researches in low-carbon economy and the reverse logistics network is plenty ,but little in the coordination with both low-carbon economy and the reverse logistics network.

This article takes the paper recycling reverse logistics network as an example. With the analyses of the relevance between them while taking the carbon as the carrier, we realize the coordination between the optimization of reverse logistics network and the low-carbon economy. It mainly displays in the following two aspects specifically.

First, the recycling of waste paper can reduce carbon emissions. From the ecological footprint analysis, the footprint of woodlands is based on the original wood. With the consumption of wood-pulp paper the paper trail, the waste paper recovery and carbon emissions reduction of the relationship is a sign of the waste paper recycling of paper consumption .To begin with, proportion of pulp and paper is about 0.9:1.

With the pulp of recovery which would be based on carbon emissions and the recovery paper analyses per ton saved carbon emissions. One ton per recycling of waste paper can be made in 0.85 million tons of paper and timber while three tons of a little off the tree grown tall tree.

Secondly, the reverse logistics network can also reduce carbon emissions. This process through the path that rearrangement of transportation planning and waste paper recovery is in a network, including the customer and processing center, the secondary market and paper. This four nodes can help determine the location of the vehicle the transport lines and reduce the amount of fuel as well as the carbon emissions.

Low-carbon economic rely mainly on carbon emissions reduction and waste paper recovery by the reverse logistics network analysis. So that the reverse network for the carbon emissions reduction has a positive role and low carbon economic and reverse the integrated logistics network show feasibility.

4 MODEL BUILDING

4.1 Model Specification

With general consideration of the costs、benefits and carbon emissions. This article sets two goals: the maximization of benefits and the minimization of carbon emission.

With the control and action of pretreatment centers number and current capacity of each node, this study count out the location of customers, garbage recycling centers, second-handed markets and paper mills under the goals while it is also capable to trace out the plan of recycling center construction and capacity during the transportation.

4.2 Model Assumption

(1) Customers as well as trash treatment plant quantity is acknowledged and each customer as well as recycling production output of trash treatment plant and price is known;

(2) All recycling product's quality is the same while part of them is secondary markets, carries on the restoration a part to the paper mill;

(3) The location of each pretreatment center is acknowledged, so as its fixed investment and capability.

(4) The location and capability of each second-handed market is acknowledged, so as each Paper Mill.

(5) The costs of each processing step and carbon emission from the three spots is known.

(6) Freight for each unit and carbon emission from each node of the network is acknowledged.

(7) The number of pretreatment centers is restricted.

(8) Only a single-round static model

4.3 Model Establishment

(1) Symbols

I : Collection of costumer

J : Collection of garbage recycling centers

P : Collection of splitting treatment centers

S : Collection of second – handed markets

H : Collection of paper mill

W_{S_S} : Unit income from paper sold from the second – handed market

W_{H_h} : Unit income from paper sold from the paper mill

X_{S_s} : Output of paper from the second – handed market

X_{H_h} : Output of paper from the paper mill

C_0 : Reverse costs from reprocessed center to customers

C_1 : Reverse costs from reprocessed center to paper recycling center

A_{1ip} : Unit transport costs from customer I to reprocessed center p

A_{2jp} : Unit transport costs from paper recycling j to reprocessed to reprocessed center p

A_{3sp} :Unit transport costs from reprocessed center p to paper recycling s

A_{4ph} : Unit transport costs reprocessed center p to paper mill h

D_{1ip} : Distance from customer i to reprocessed center p

D_{2sp} : Distance from paper recycling center to reprocessed center p

D_{3sp} : Distance from reprocessed center p to secondary markets s

D_{4ph} : Distance from reprocessed center p to paper mill h

f_p : Fixed cost of the reprocessed center p per year

C_D^* : Carbon emission from each unit of transport

λ : Coefficient of carbon emission of one ton waste paper

α_p^P : Recovery rate of treatment center

α_h^H : Production rate of paper mill

Q_p^P : Operational capacity restrictions of treatment center

Q_s^S : Operational capacity restrictions of second – handed market

Q_h^H : Restoration ability limitation of paper mill

γ : Restiction of the number of Treatment center

M : Carbon emissions from transportation before optimization

(2) Decision variable

P_p : 0-1 variable, 1 represents to buid reprocessed center, 0 represents not

$X_{I_i}^P$: the amount of paper reversed from reprocessed p to costumer i

$X_{J_j}^P$: the amount of paper reversed from costumer p to recycling center j

X_{1ip} : the amount of paper reversed from customer I to reprocessed center p

X_{2jp} : the amount of paper reversed from recycling center j to reprocessed center p

X_{3sp} : the amount of paper reversed from reprocessed center p to secondary market s

X_{4ph} : the amount of paper reversed from reprocessed center p to paper mill h

(3) Objective function

$$Max[\sum_I\sum_P D_{1IP} + \sum_J\sum_P D_{2JP} + \sum_P\sum_S D_{3PS} + \sum_P\sum_H D_{4PH} - M + \lambda(\sum_s X_{S_S} + \sum_h X_{H_h})]*48.6$$
$$+\sum_S W_{S_s} * X_{S_s} + \sum_H W_{H_h} * X_{H_h} - \sum_I C_0 * X_{I_i} - \sum_J C_1 * X_{J_j}$$
$$-\sum_I\sum_P A_{1ip} * D_{1ip} * X_{1ip} - \sum_J\sum_P A_{2jp} * D_{2jp} * X_{2jp} - \sum_P\sum_S A_{3ps} * D_{3ps} * X_{3ps} -$$
$$\sum_P\sum_H A_{4ph} * D_{4ph} * X_{4ph} - \sum_P C_{3p} * X_{P_p} - \sum_H C_{4h} * X_{H_h} - \sum_H f_p P_p$$

(4) Constraints

$$X_{I_i} = \sum_P X_{1ip} \tag{1}$$

$$X_{J_j} = \sum_P X_{2jp} \tag{2}$$

$$\alpha_p^P(\sum_I X_{1ip} + \sum_J X_{2jp}) = \sum_S X_{3ps} + \sum_H X_{4ph} \tag{3}$$

$$\sum_P X_{3ps} \le X_{S_s} \tag{4}$$

$$\alpha_h^H \sum_P X_{4ph} = X_{Hh} \tag{5}$$

$$\sum_I X_{1ip} + \sum_J X_{2jp} \le Q_p^P * P_p \tag{6}$$

$$\sum_P X_{3ps} \le Q_s^S \tag{7}$$

$$\sum_P X_{4ph} \le Q_h^H \tag{8}$$

$$\sum_p P_p \le \gamma \tag{9}$$

$$P_p = 0,1 \quad \forall p \in P \tag{10}$$

$$\forall X \ge 0 \tag{11}$$

Constraints (1) ~ (5) is for the customers, garbage collection center, processing center, the second-handed market and paper mill .Five points in the flow of conservation are based on the type constraint; （6）~ (9) are based on the limitation of processing center, the second-handed market and paper mill. (10) ~ (11) concerns on variable value.

5 ANALYSIS

A waste paper recycling centre of the network has three large waste treatment centre: a seconded market, one paper mill, waste paper from one customer and a garbage collection centre.

The treatment center's recycling rate is 70% while the production rate of the paper mill is 35%.The recovery for customer and garbage collection centre from the pretreatment is 39000 tons and 91000 tons. The second-handed market and paper mill can get 44,000 tons and 59000 tons from the pretreatment center.

The second-handed market's selling price of paper is 1500 Yuan per ton while the paper mill's is 1300 Yuan. The transportation costs from the pretreatment center to the second-handed market are 1.3 Yuan while one from pretreatment center to the paper mill is 1.2 Yuan. The transportation costs from the customer to the pretreatment center is 1.2 Yuan while one from recycling center to pretreatment center is 1.1 Yuan. Cost of customer and recycling centers to be dealt with the transportation is 1.1 and 1.2 billion Yuan. In the past, emissions of carbon from transportation was 620 tons a year while transportation of carbon emissions from 0.00042 tons for a ton and paper for discharge coefficient is 0.0026 one unit of data.

Table 1: Distance among customers, recycling center, reprocessed center and paper mill.

	Distance（Km）		Distance（Km）
Distance from customer to reprocessed center 1	3	Distance from reprocessed center 1 to recycling center	15
Distance from customer to reprocessed center 2	2	Distance from reprocessed center 2 to recycling center	20
Distance from customer to reprocessed center 3	5	Distance from reprocessed center 3 to recycling center	10
Distance from recycling center to reprocessed center 1	15	Distance from reprocessed center 1 to paper mill	20
Distance from recycling center to reprocessed center 2	10	Distance from reprocessed center 2 to paper mill	23
Distance from recycling center to reprocessed center 3	20	Distance from reprocessed center 3 to paper mill	15

Table 2: The maximum processing ability ofreprocessed center, secondary market and paper mill.

P	**P**	**P**	$X^1_{I_i}$	$X^2_{I_i}$	$X^3_{I_i}$	$X^1_{I_i}$	$X^2_{I_i}$	$X^3_{I_i}$
0	**0**	**1**	**0**	**0**	**39000**	**0**	**0**	**91000**
1	**0**	**0**	**39000**	**0**	**0**	**91000**	**0**	**0**
1	**1**	**0**	**14500**	**24500**	**0**	**91000**	**0**	**0**
0	**1**	**0**	**0**	**39000**	**0**	**0**	**91000**	**0**
0	**1**	**1**	**0**	**12500**	**26500**	**0**	**78500**	**12500**

With the data for the objective function and constraints, we use lingo11. 0 to achieve the result： Recycling centre will only transport waste paper to the further processing center while customers sent the waste to the waste treatment centre 1 and 2. Finally, the maximum income is 2670000 Yuan. Results shown in Table 3：

Table 3: Results of the modelling.

	results（ton）
Maximum ability of reprocessed center	150000
Maximum ability of secondary market	100000
Maximum ability of paper mill	120000

Figure of table 3 shows that the number of Figure of table 3 shows that the number of pretreatment center is two at most. Customers can deliver waste to pretreatment centre 1 and 2 while waste paper recycling centre will always be handled by the central treatment centre. 1 and 2 will be sent to the second-handed market. The waste paper from the pretreatment center 2 of the waste treatment centre will be sent to paper mill.

6 CONCLUSIONS

On the basis of the low-carbon economy and reverse logistic network, this article works on the waste paper recovery and recycling network .It takes waste paper recycling reverse logistic network as example as well. It argues for the feasibility of the model in which low-carbon economic and the optimization of the reverse logistics network can perfectly combine. With the construction of the model, it can achieve the two goals while it is also effective.

However, this article is base on the assumption of the maximize benefit from each node in the supply chain and the minimization of carbon emission, which leads to the contradiction that either the whole or the each node can achieve the maximize profit. Therefore, the next step may be based on this and focus on the benefit distribution in the method the Nash Equilibrium, a principles of economics.

REFERENCES

Stock J. R. Development and implementation of reverse logisties Programs. Oakbrook，IL: Council of logisties management，1998.

Fleisehmanna M，Krikke H. R.，Dekker R.，et al. A characterization of logisties networks for Product recovery. Omega, 2000，Vol.28(6):653-666.

达庆利等.逆向物流系统结构研究的现状及展望.中国管理科学，2004，vol.12(l):131-138.

Fleiselllnarin M. Reverse logistics network structures and design. Erim report series research in management，2001.

Jayaraman V.，Guide J. V.，Srivastava R. A closed-loop logisties model for remanufacturing . Journal of the operational research society，1999，Vol.50:497-508.

秦小辉.废旧电子产品逆向物流网络优化设计研究.西南交通大学，2008，vol.29(128):14-16.

Listes O. A decomposition approach to a stochastic model for supply-and-return network design. Econometric Institute Reports EI2002-43.

马祖军，张殿业，代颖.再制造逆向物流网络优化设计模型研究.交通运输工程与信息学报，2004，Vol.2(2):53-58.

赵宜，尹传忠，蒲云.回收物流设施多层选址模型及其算法.西南交通大学学报，2005，Vol.40(4):530-534

邢继润.发展低碳经济的公共政策研究:[D].华中科技大学，2009

Neto J. Q. F., Bloelnhof-Ruwaard J. M.，van Nunen J. A. E. E. et al. Designing and evaluating sustainable logistics networks. Erasmus research institute of management report series research in management，ERS-2006-003-LIS，2006.1.

Bloelnhof-Ruwaard J. M.，Wassenhove L. N. Van，Gabel H. L.， et al. An environmental life cycle optimization model for the European pulp and paper industry，*Omega*，*Intemational joumal of management science,* 1996，Vol.24(6):615-629