The Study of Recycling System of Waste Household Appliances Based on Network Information Platform

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Abstract. In recent years, people have paid more and more attentions to recycling of waste Household appliances reasonably, which has become a new field of development in reverse logistics as China enters the peak of obsolescence. There are great differences between recycling waste household appliances and sales in forward logistics. Generally, quantity and quality of recycling, recovery time and other factors are not known previously so enterprises find it difficult to recycle the waste Household appliances. In this paper, with the help of constructing network information platform for waste home appliances, it develops a new model of “internet +recycling”. At the same time, it increases information transparency that the customers communicate with recycling enterprises, and reduce the characteristics of uncertain in the process of recycling. There is no doubt it provides a foundation for the study of recycling system.

1. Introduce
Now China’s household appliances have entered the peak of obsolescence as one of the largest household. According to statistics, the theory number of discarded home appliances in 2017 had reached 125,230,000. Among them, the number of television is 32,160,000; The refrigerator is 24,390,000; The washing machine is 16,200,000; The air conditioner is 27,230,000; The computer is 25,240,000[1]. The recycling of waste household appliances in reverse logistics have become a new area of development of China’s logistics. Collecting the waste appliances properly can not only solve the situation of dwindling resources, but also it is of great significance to build a environment-friendly and development of circular economy society.

Reverse logistics which has the characteristics of dispersion, diversity and demand of uncertainty in China started relatively late comparing with foreign countries so that it makes more complex research reverse logistics[2]. In this paper, it completes the online communication between customers and recycling enterprises in real time through the construction of the network information platform of waste home appliances for recycling. Customers are able to look up the the latest information of recovery, and feedback related information of appliance by the information platform. As a result, it enhances information exchange between the customer and the recycling enterprises.

2. The construction of the network information platform
The recycling website of waste household appliances is infrastructure and information platform for the recycling company, which makes use of network technology, realizes the recovery of information exchange between firms and customers, so that the recycling system will be more standardization.
2.1 Website design
Recycling website system currently uses generic B/S mode in the Internet, divided into three layers[3].

1. Front-end application layer: It provides interactive services for the users with connecting to the Internet. For example: customer registration, recycling information inquiry; related website links; feedback, etc.

2. Intermediate information processing layer: It is the non-public applications of system, such as management and maintenance of the entire system; supervision recycling activities and data statistics, and feedback; recycling enterprise internal management and external communication; business process handling.

3. Underlying data access layer: It includes accessing to the core database, query, data analysis, extraction and data correction.

2.2 Basic modules
Used household appliances of recycling site has three main modules, including the user layer, business layer, service layer[4], shown in Figure1.

1. User layer: The user logs in the recycling websites after finishes registering, then refer to the latest recycling information; On the one hand it is necessary to fill out basic personal information such as home address, telephone number, etc for the users, which contributes recycling companies collect the goods; On the other hand the user registers the basic information of recycling appliances, such as the type, age, extent of damage of household appliances, so that recycling companies can get the preliminary understanding for waste household appliances.

2. Business layer: The recycling business can announce the latest price of recovery and recycling policies on the websites in real time, increase enterprise awareness, get more waste home appliances into the standard channel.

3. Service layer: Not only can it communicate with customers, but also it can answer the problems from customers; It arranges vehicles to collect waste household appliances and optimizes the routes; At last, it returns the customers a visit, accepts the customers' recommendations and improves the unreasonable recycling program.

![Figure1. The construction of waste household appliances website for recycling](image)

2.3 Basic process operations
With the help of computer network technology, users basically needn't leave home and discarded appliances can be recycled. The specific process is shown in Figure 2. First users register recycling
site, become a member, then log on to the site. Second, users fill out basic information of used household appliances, and the staff call the recycling users to verify the recovery of information after receiving recycling information. The recycling business will begin the vehicles loading and carry out door-to-door recycling service. Finally, recycling companies return the customers satisfaction visit and maintain the customers.

![Figure 2. Basic procedure](image)

3. The construction of recycling system of waste home appliances

3.1 Recycling network of waste home appliances

For a long time, the recycling of waste home appliances recycling has been in a fragmented, secondary use, "indigenous" decomposition (manual, acid soak, fire, etc.) and other low-level mode as one of the largest household appliance production and consumption countries. These modes are not only inefficient, not form scale, but also pollute the environment [5]. In recent years, as people accepts Extended Producer Responsibility widely, more and more companies realize the importance of recycling waste household appliances. Traditional product process has begun to flow from the "resources - production - consumption - waste" to "resource - production - consumption - renewable resources - waste"[6], as shown in Figure 3.

![Figure 3. Recycling network of waste household appliance](image)

Recycling enterprises collect waste household appliances which be scattered in the hands of customers, and eventually shipped to a recycling center. Used household appliances in recycling centers will be cleaned, tested, dismantled, classified and so on. For reusable products and parts, they will be repaired, recover their functions, and re-enter the market; But the components repaired which can not be re-used will be returned to material suppliers on the upstream; The waste generated in spin-off process will be disposed properly[7].

3.2 Location question of collecting station and collecting center

The question of location is pivotal that can save investment costs of early construction, reduce business risk in recycling system of waste household appliances recycling system.

3.2.1 Description of the problem
There exist two forms, one form is new-built, the other one is expanded-built for the location problems. Expanded-built can utilize the distribution points in distribution network of forward logistics, then expand its scale on the basis of the origin distribution points. It can make full use of the existing facilities, so the costs of expansion are generally lower than the new cost. Generally, enterprises regard the lowest cost of operation as the optimal conditions in the recovery system. Operation costs considered in this paper are mainly composed of two parts: (1) the cost to build new-built or expanded-built collection stations and collection centers; (2) transportation cost that waste household appliances shipped from the customer to the recycling stations and shipped from the Recycling stations to recycling centers.

3.2.2 Model construction

(1) Assumptions

Hypothesis 1: The waste household appliances will be transported to the collecting center when the collecting station close to its storage capacity.

Hypothesis 2: The number of locations that be used to set up the collecting stations and the collecting centers is limited.

Hypothesis 3: Regardless of the actual distribution of road and traffic, the transportation costs of discarded household appliances units are proportional to the distance of transport units.

Hypothesis 4: The number of waste household appliances recycled in the collecting stations is equal to the number of waste household appliances recycled in the collecting centers.

Hypothesis 5: Do not consider storage capacity of collecting centers.

Hypothesis 6: The location of collecting stations have no effect on the number of recycling used appliances.

(2) Model parameter and decision variables

Parameters:

- \( i \): customers (1, 2, ..., I) that produce waste household appliances;
- \( a_i \): waste household appliances number from customer \( i \) per day;
- \( K \): optional collecting stations (1, 2, ..., J + M), including J new-built collecting stations, M distribution stations which be expanded-built for collecting stations;
- \( N \): optional collecting centers (1, 2, ..., L + S), including L new-built collecting centers, S distribution centers which be expanded-built for collecting centers;
- \( j \): fixed cost of new-built collecting station at the location \( j \);
- \( m \): fixed cost of expanded-built collecting station at the distribution station \( j \);
- \( l \): fixed cost of new-built collecting center at the location \( l \);
- \( s \): fixed cost of expanded-built collecting center at the distribution center \( s \);
- \( W \): days;
- \( d_{ik} \): distance from the customer \( i \) to the collecting station \( k \);
- \( d_{kn} \): distance from the collecting station \( k \) to the collecting center \( n \);
- \( a \): unit distance cost per recycling unit product;
- \( N_1, N_2 \): the maximum number of collecting stations/collecting centers;
- \( B \): the maximum storage capacity of collecting stations;
- \( D \): the longest distance which collecting stations service;
- \( \psi \): any of a large numbers;

Variables:
\[ X_k = \{ 1 \} \] if a collecting station is open at the location \( k \);
otherwise;
\[ Y_n = \{ 1 \} \] if a collecting station is open at the location \( n \);
otherwise;
\[ Z_{ik} = \{ 1 \} \] if the collecting station \( k \) recycle the products from the customer \( i \);
Otherwise;
\[ Z_{kn} = \{ 1 \} \] if the collecting center recycle the products from the collecting station \( k \);
Otherwise;

(3) Mathematical model

The construction fee of collecting stations and collecting centers
\[ C_1 = \sum_{j=1}^{l} C_j \sum_{i=1}^{l} (C_n X_n) + \sum_{j=1}^{l} C_j \sum_{i=1}^{l} (C_n X_n) = (3.1) \]

The transportation fee of waste household appliance:
\[ C_2 = \alpha \sum_{j=1}^{l} X_j + \sum_{i=1}^{l} \sum_{k=1}^{l} (a_i Z_{ik} d_{ik} + b_k Z_{kn} Y_{kn} d_{kn}) = (3.2) \]

To sum up, the mathematical model as follows:
\[ F = \text{Min} C_1 + C_2 = \sum_{j=1}^{l} X_j + \sum_{i=1}^{l} \sum_{k=1}^{l} (a_i Z_{ik} d_{ik} + b_k Z_{kn} Y_{kn} d_{kn}) = (3.3) \]

Subject to:
\[ \sum_{k=1}^{l} Z_{ik} = 1, \forall i \in I \] (3.4)
\[ \sum_{i=1}^{l} Z_{ik} \leq X_i, \forall k \in J + M \] (3.5)
\[ \sum_{i=1}^{l} Z_{ik} = 1, \forall k \in J + M \] (3.6)
\[ \sum_{i=1}^{l} Z_{ik} \leq X_i, \forall n \in L + S \] (3.7)
\[ \sum_{i=1}^{l} a_i Z_{ik} \leq B Z_k, \forall k \in J + M \] (3.8)
\[ d_{ik} Z_{ik} \leq d, \forall k \in J + M \] (3.9)
\[ \sum_{k=1}^{l} X_k \leq N_1 \] (3.10)
\[ \sum_{a=1}^{l} Y_a \leq N_2 \] (3.11)
In this model, the objective (3.3) is to minimize the operation costs including the opening costs of collecting stations/collecting centers and the total transportation costs from customers to collecting centers. Constrain(3.4) ensures each of the customers only can transport waste household appliances to a collecting station. Constrain(3.5) assures the used household appliances are recycled only when the collecting station is set up. Constrain(3.6) makes sure the waste household appliances are shipped a collecting center. Constrain(3.7) enforces the used household appliances are transported to the collecting center only when the collecting center is set up. Constrain(3.8) explains about the storage capacity of collecting stations. Constrain(3.9) limits the distance the collecting stations can service. Constrain(3.10-3.11) represents the number of collecting stations and collecting centers. Constrain(3.12) is the value of the variables.

### 3.2.3 Illustrative example

A company plans to recycle waste household appliances through establishing the recycling stations and recycling centers. Now they make a survey and find there are 12 customer groups, 10 potential recycling stations, including 7 new-built recycling stations and 3 distribution stations, which 1, 2 ... 7 mark new-built recycling stations, 8, 9, 10 mark expanded-built recycling centers on the basis of distribution stations in this area. Potential recycling centers have three, one of them is new-built recycling center, the others are expansion of the distribution centers for the recycling centers. Now the company has to select the appropriate recycling stations and recycling centers from 13 appoints in order to minimize total cost of the operation. The amount recovered waste household appliances from the customer every day and the distance from customers to recycling stations shown in table 1. The table 2 provides the distances between the recycling stations and the recycling centers. The remaining parameters as follows: \( C_I = 300,000 \text{ yuan} \), \( C_m = 20,000 \text{ yuan} \), \( C_j = 300,000 \text{ yuan} \), \( C_s = 150,000 \text{ yuan} \), \( B = 20 \text{ tons} \), \( w = 365 \text{ days} \), \( D = 10 \text{ km} \), \( a = 1 \text{ yuan/ton km} \).

| Customers | Output (ton/day) | The distance between the customers and the collecting stations (kilometers) |
|-----------|-----------------|--------------------------------------------------------------------------|
|           |                 | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| 1         | 2.5             | 1.6| 6.5| 9.8| 7.2| 5.8| 2.7| 2.8| 10.2| 0.8| 11.1|
| 2         | 3.0             | 3.8| 2.6| 3.6| 3.8| 4.0| 2.7| 4.5| 4.7| 4.8|
| 3         | 3.4             | 5.9| 2.6| 4.0| 3.5| 4.8| 6.7| 13.3| 3.8|
| 4         | 2.8             | 8.1| 8.7| 2.2| 2.4| 2.7| 7.1| 7.6| 7.2| 9.1| 7.9|
| 5         | 3.8             | 4.6| 5.2| 2.5| 1.8| 2.1| 3.4| 4.1| 5.7| 4.9| 6.0|
| 6         | 1.8             | 0.3| 4.4| 7.7| 6.3| 4.9| 0.6| 0.6| 8.6| 1.3| 9.0|
| 7         | 2.7             | 2.6| 2.1| 5.2| 4.6| 5.0| 1.7| 2.4| 6.0| 3.8| 6.9|
| 8         | 4.0             | 8.7| 3.8| 6.1| 7.4| 8.9| 7.5| 8.2| 0.5| 9.6| 0.6|
| 9         | 3.7             | 3.7| 7.3| 9.2| 5.7| 4.7| 4.4| 4.4| 10.1| 3.1| 10.5|
| 10        | 3.6             | 10.8| 5.9| 9.5| 12.2| 12.1| 9.8| 10.5| 5.3| 11.0| 4.8|
| 11        | 4.2             | 4.1| 4.5| 6.6| 4.5| 3.1| 3.1| 3.5| 7.5| 3.3| 8.0|
| 12        | 3.9             | 4.2| 6.5| 8.6| 5.1| 3.6| 4.2| 4.3| 9.3| 3.7| 9.7|
Table 2. The distance between the collecting stations and the collecting centers

| Collecting centers | The distance between the collecting stations and the collecting centers |
|-------------------|-------------------------------------------------|
| 1                 | 14.0                                            |
| 2                 | 11.0                                            |
| 3                 | 5.2                                             |
| 4                 | 8.1                                             |
| 5                 | 8.5                                             |
| 6                 | 12.0                                            |
| 7                 | 12.6                                            |
| 8                 | 10.8                                            |
| 9                 | 13.3                                            |
| 10                | 11.2                                            |

3.2.4 Computation result and analysis

In terms of the above analysis, we found that minimizing operating costs is a typical 0-1 mixed integer linear programming model in this paper. For solving the model, we bring the data in LINGO 14.0 which has been compiled, obtained the results by calculation: \( F = 1.129025 \times 10^6 \), it indicates the minimizing operating costs of the recycling company is 129,025 yuan; \( X_k \) is 1 when \( k \) is equal to 3, 6, 8, 9, 10. It means we will new build the collecting stations at the location 3 and 6. At the same time, the distributions stations 8, 9, 10 will be expanded-built for the collecting stations. \( Y_n \) is 1 when \( n \) is equal to 3. It shows we will built the collecting center on the basis of the distribution center 3. Therefore, we should combined reverse logistics network with forward logistics network as much as possible and make full use of existing infrastructure for recycling waste household appliances in forward logistics when we investigate the location problems of used household appliances in recycling network. As a result, it greatly reduces the cost of recovery system.

4. Conclusion

In this paper, we centrally collect the waste household appliances which be scattered in the hands of customers and uniformly dispose them by constructing network information platform of waste household appliances for recycling. We expect to get rid of the traditional model of unreasonable collecting. The paper focuses on the siting about collecting stations and collecting center in recycling system. We construct a model of minimizing operating costs, which is used to study the location questions, and ultimately solve the model applying LINGO 14.0. But it still have some deficiencies, the model is in ideal state. Due to the characteristics of uncertainty of reverse logistics, the quantity and quality of waste household appliances can not be determined in advance. Research on uncertainty of reverse logistics is still the focus of the study in the future.

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