REVERSE LOGISTICS SYSTEM FOR RECYCLING : EFFICIENT COLLECTION OF ELECTRICAL APPLIANCES

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Abstract: In April 2002, the Japanese government launched new regulations focused on electrical appliances. The manufacturers and importers of the electrical appliances defined in the regulation are being held responsible for their products throughout the useful lifetime. This paper investigates how a reverse logistics flow pattern reverts a conventional logistics flow in the product sector of electrical appliances, and how this process can produce efficient systems and services in order to achieve high reverse logistics performance. The research approach includes the following points: (1) Estimation of the type and amount of post-consumer waste of current electrical appliances and analysis of the expected type, size, and number of storage facilities are analyzed. (2) Development of a simulation model to analyze the suitable allocation of storage facility in the area and the efficient service is considered.

Key words: logistics, reverse logistics

1. Introduction

The increase in environmental degradation is one of the most challenging problems in our society. The conservation of natural resources and the reduction of CO_2 emissions are major issues all over the world. At the same time, consumer awareness has increased, and it is necessary for companies to gain the goodwill of their customers to obtain competitiveness in the market. Reverse logistics, taking back and recycling the products at the end of their useful life, helps alleviate these problems, and government regulations are forcing companies to adopt reverse logistics into their business practice.

Most research discussing a facility location not on the basis of reverse logistics but purely on the logistics network, has focused on transportation, distance, or cost. Kuse (1999) has taken into account the set-up cost of establishing the facilities including land cost as well as construction cost. Weigel (1992) developed a model incorporating environmental aspects into the facility location model. Taniguchi *et al.* (1998) presented a model, which optimized the size and location of logistics terminals by considering the amount of air pollution from trucks.

Many researchers have discussed reverse logistics system planning for used products disposition (Bettac *et al*., 1999; Linton, 1999; Yoshida *et al.*, 1999; Zhang *et al*., 2000) and consider several criteria for establishing a good disposition system for used products (Uzroy and Vekatachalam, 1998; Ammons *et al.*,1999; Newton *et al*, 1999). Most of these studies present mathematical models that solve the problems as reverse network flow problems in order to obtain an optimal infrastructure design.

This paper presents a method to achieve an efficient reverse logistics system. First, a conceptual framework of reverses logistics system is presented and current state of reverse logistics systems for used electrical appliances in Japan is reviewed. Since reverse logistics systems for electrical appliances have just started in Japan, not so much data for this field is available to the public. An estimation method is developed to estimate the amount of used electrical appliances. Secondly, the proper location of storage facilities for used electrical appliances are considered in terms of the sum of the distance from collecting points (zone centroids) representing customers to dummy points for recycling plants in Shiga prefecture.

2. Reverse logistics system

2.1 Conceptual framework for reverse logistics system of used electrical materials

Since used electrical materials are mainly composed of iron, glasses, and plastics, a reliable reverse logistics system is needed which can reduce the amount of illegal disposal of used materials. Also, used electrical materials are value-added materials, and the efficient way of utilizing value has to be considered. To achieve high reverse logistics performance of used electrical materials, it is necessary to set proper size, number, service and location of storage facilities, in order to minimize transportation distance or transportation cost, and to increase the amount of materials brought to recycling.

The goal of a reverse logistics system is to bring benefit to both public and manufacturers in terms of the reduction of environmental impact and transportation cost. The objectives of any such system are to reduce the total distance of transportation, increase the number of used appliances collected from consumers, reduce the amount of used appliances carried to recycling plants inefficiently, connect reverse logistics to forward logistics in an efficient way, and deal with other electrical appliances. In Figure2-1, second-hand shops are set next to storage facilities to reduce additional transportation. With sorting functions inside storage facilities, the reusable products are sent directly to second-hand shops. This, moreover, allows the smooth flow of reusable products from second-hand shops to customers. Exchange of information between consumers and second-hand shops are newly considered, and since retail outlets collect the used appliances from consumers, the information on used products from consumers is provided to retailers.

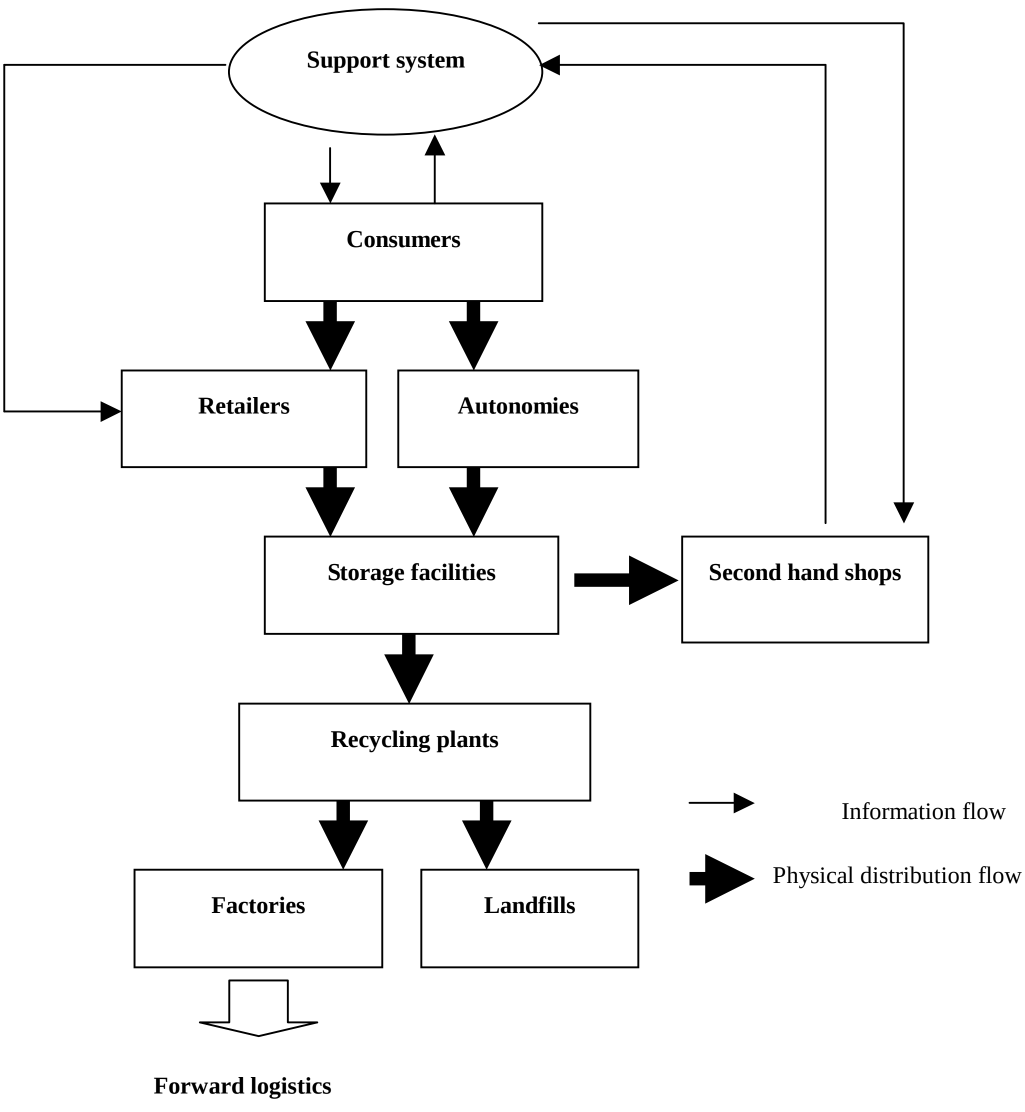


Figure 2-1 Conceptual framework of reverse logistics

2.2 Current reverse logistics system for used electrical appliances in Japan

A key element of reverse logistics is the collection and recycling of post- consumer waste. In April 2002, new Japanese government regulations brought in by the administration of the Ministry of Economy, Trade and Industry focused on electrical appliances, such as refrigerators, air conditioners, television sets and washing machines. In these regulations, the manufacturers and importers of these appliances are being held responsible for their products from cradle to grave. Around 60 thousand used electrical appliances per month are collected in the recycling plants of Japan (Figure2-2). Around 35% of them are television sets, and 26% of them are refrigerators (Figure2-3).

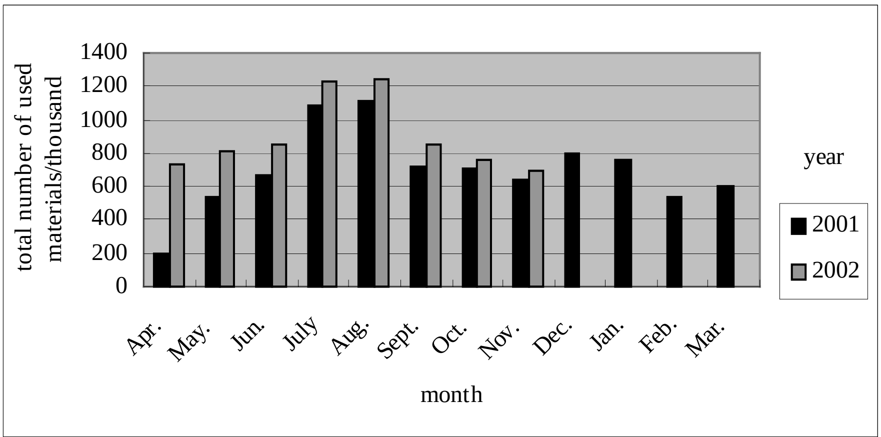


Figure 2-2 Total number of used refrigerators, television sets, washing machines, and air conditioners collected in recycling plants of Japan

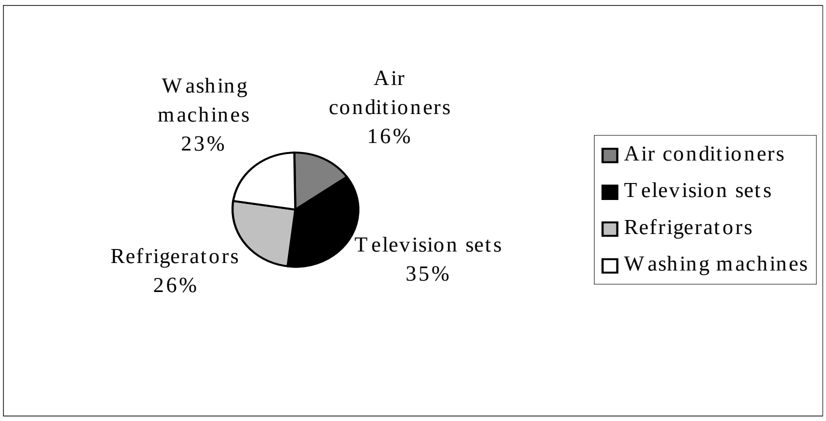


Figure 2-3 Ratio of electrical appliance types collected at recycling plants in Japan in 2001

In figure 2-1, the conceptual framework of reverse logistics is presented. In figure 2-4, current reverse logistics are reviewed. In the first step, the final consumers are required to bring these appliances, when the time comes for their retirement, to the retailers or autonomies which are regional governmental office. Secondly, all of these appliances from retailers are taken to the storage facilities, which are assigned to each area by governmental regulations and which store the appliances temporarily in each area through the distribution systems of retailers. Finally, the appliances in each storage facility are sent to a recycling plant.

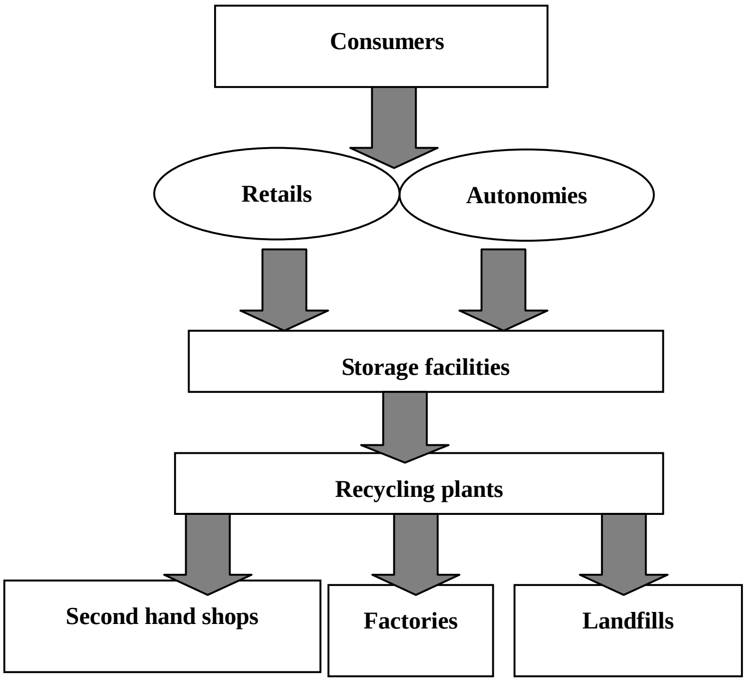


Figure 2-4 Current flow of reverse logistics

Currently, there are 190 storage facilities and 38 plants for electrical appliances in Japan. Figure 2-5 illustrates 20 of the storage facilities and 3 plants in Kansai region.

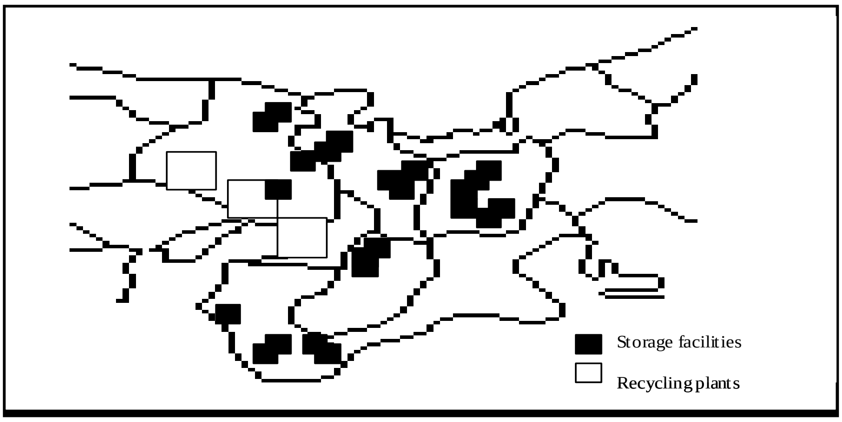


Figure 2-5 Location of recycling plants and storage facilities in Kansai district

The used electrical appliances are recycled at the proper recycling plants. Most of them are recycled to iron, plastics, and glasses (Figure 2-6).

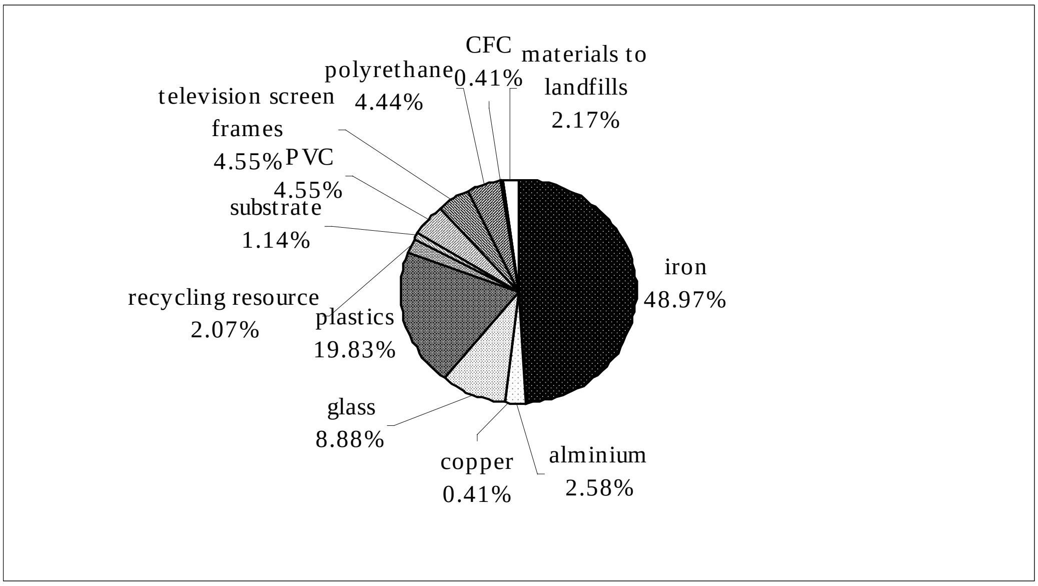


Figure 2-6 Weight ratio of recycled materials at a recycling plant

3. The State of Used Electrical Appliances in Shiga Prefecture

3.1 Current state

As has been already mentioned above, currently four types of used electrical appliances, namely refrigerators, washing machines, air conditioners, and television sets, are handled in reverse logistics system in Japan, in accordance with the governmental regulation. However, it is necessary to bring more used electrical appliances into the reverse logistics system in order to develop more efficient and environmentally friendly systems. At the moment, a limited amount of data for reverse logistics system is available to the public in Japan, including the amount of electrical appliances handled at storage facilities in the specified area. Therefore, in order to conduct an analytical approach, the type and amount of post-consumer waste of electrical appliances have to be estimated.

For the analytical approach, Shiga prefecture is applied to determine the location of consumer and the amount of used electrical appliances. Shiga prefecture consists of six parts, Konan area, Kosei area, Koto area, Kohoku area, Higashiomi area, and Koga area. The amount of used electrical appliances from each area is being estimated.

3.2 The type and amount of used electrical appliances

Refrigerators, washing machines, air conditioners, and television sets are already with current reverse logistics system. Personal computers, VTRs, stereo sets, microwave ovens, and cleaners are being newly considered for possible inclusion. Data has been obtained from explanatory notes in the Census of commerce and electrical appliances industry handbook, and the amount of used electrical appliances and the length of each electrical appliance's usage from each area are being evaluated.

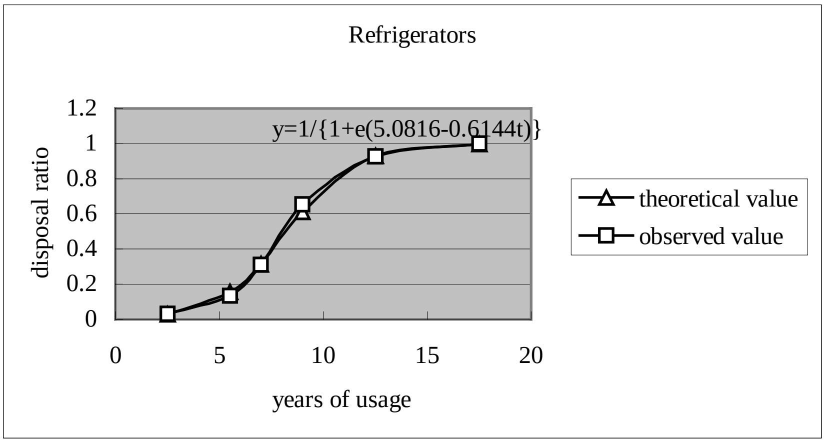
First, in order to estimate the relationship between the ratio of used electrical appliances disposal and years of usage, regression models are developed. The ratio of used electrical appliances disposal is given by:

$$\mathbf{y_c = 1/\{1+e^{(a+bt)}\}} \qquad \text{--------------(1)}$$

y_c : cumulative ratio of annual used electrical appliances disposal / year

t: the number of years of usage

Using formula (1), the examples below are obtained (Figure3-1).



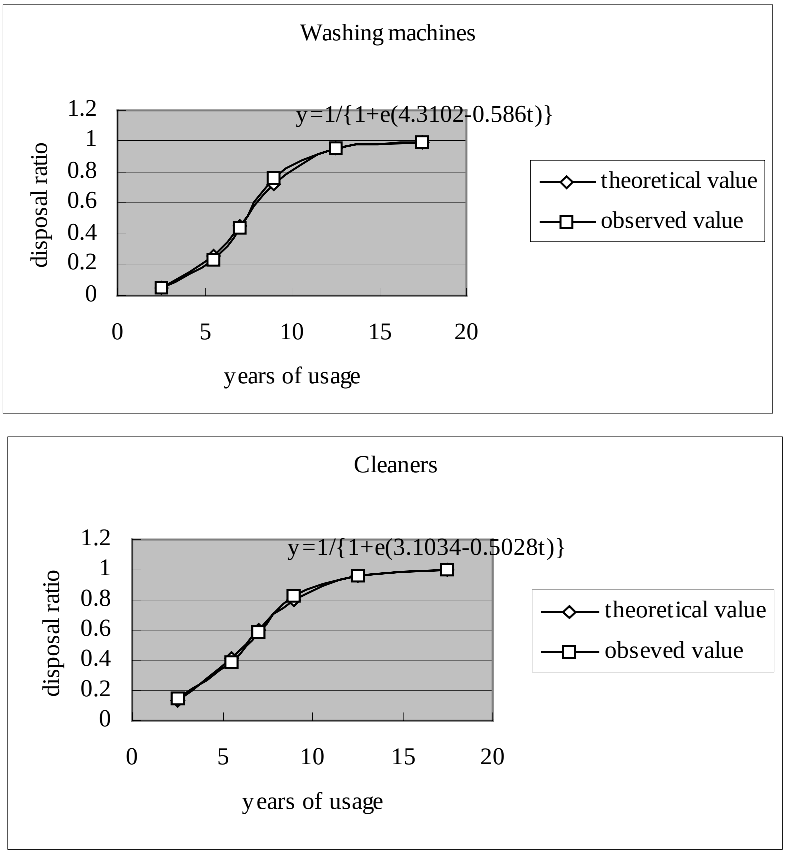


Figure 3-1 Relationships between disposal ratio and the number of years of usage

Secondly, utilizing the yearly gross sales and ratio of disposal gained from the logistics curbs, the number of used electrical appliances disposal is calculated. From the cumulative ratio of used electrical appliances disposal, the yearly ratio of used electrical appliances disposal is obtained. The number of used electrical appliances disposal is expressed as:

$$N = y_y \frac{S}{x} \qquad \text{----------(2)}$$

N: the number of used electrical appliances disposal / year

y_y: yearly ratio of used electrical appliances disposal

S : yearly gross sales

x: the average cost of each electrical appliance

From formula (2), the number of used appliances is obtained. Using the data of yearly gross sales until 1999, in figure 3-2, the discharge ratio of used refrigerators in Shiga prefecture is calculated as an instance.

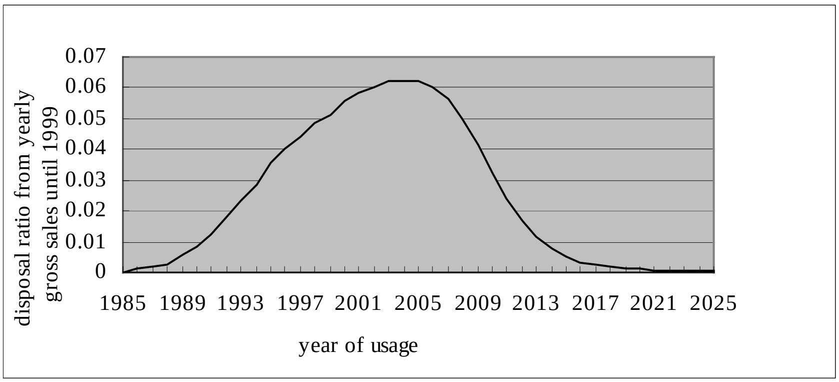


Figure 3-2 Relationship between the discharge ratio of used refrigerators and the year of usage in Shiga

4. Suitable number and location of storage facilities

4.1 Selection of proper storage facilities

A simulation model is developed to investigate the location and number of storage facilities and to minimize the total ton km of used electrical appliances from collecting points (centroids of customers) to recycling plants indicated by dummy points.

Twenty-seven of major carrier's depots exist in Shiga prefecture including six storage facilities currently utilized for used electrical appliances. Considering the number of carrier's depots existing in Shiga prefecture, this study assumes that there are twenty-seven possible storage facilities in Shiga prefecture.

Total ton km from the collecting points (zone centroids of customers) to recycling plants is calculated according to the following method: First, road network is obtained from a digital map and the number of nodes and links is set up on the road network. Secondly, collecting points (centroids of customers) and the location of existing carrier's depots including current storage facilities are allocated at each node. Then the length of links is calculated. Thirdly, three cases are set up depending on the condition of the situation. Fourthly, a simulation model is done. The used appliances from collecting points are sent to the closest storage facilities and those appliances collected at proper storage facilities are brought to the closest dummy points for recycling plants. The total ton km from collecting points to recycling plants is calculated.

4.2 Base condition

(1) The used electrical appliances handled at storage facilities

The amount of used electrical appliances of thirty-eight autonomies in year 2000 was estimated based on the number and usage length of electrical appliances and the population in each zone. Also, since only a relative amount of used materials from autonomy are utilized in this calculation, utilized data on the amount of used appliances in this research are restricted to pre-2000 figures.

It is assumed that nine types of used electrical appliances are handled at storage facilities, such as refrigerators, washing machines, air conditioners, microwave ovens, television sets, cleaners, personal computers, electric fans.

(2) Collecting points

Considering the geographical allocation of customers, at least one collecting point is set in the centorid of autonomies in Shiga prefecture. Also, in the designated zones one additional collecting point is set up for every one thousand increase in population.

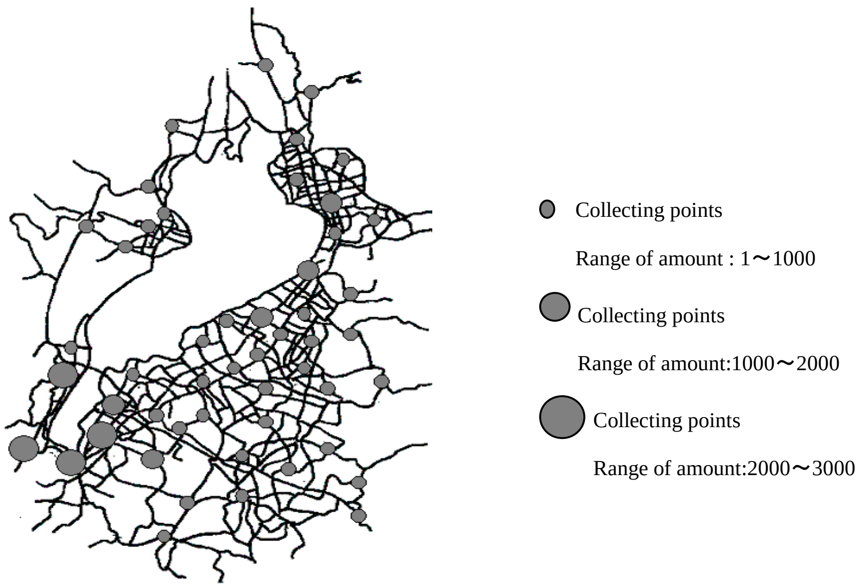


Figure 4-1 Allocated collecting points and the amount of discharge

(3) Carrier’s depots

There are twenty-seven existing major carrier’s depots including six storage facilities for electrical appliances in Shiga prefecture. Collected used materials are stored and sorted out according to types and conditions in the depots. The twenty-seven carrier’s depots are utilized as possible storage facilities for used electrical appliances in the calculation (Figure4-2).

(4) Recycling plants

Since recycling plants are located outside collecting areas, the recycling plants are indicated by dummy points. The dummy points are set at the boundary of collecting area according to the road network. Currently, three recycling plants are operated in the Kansai region and one in the Tokai region. Considering the road network, three dummy points to these plants are located at the boundary of Shiga prefecture (Figure4-2).

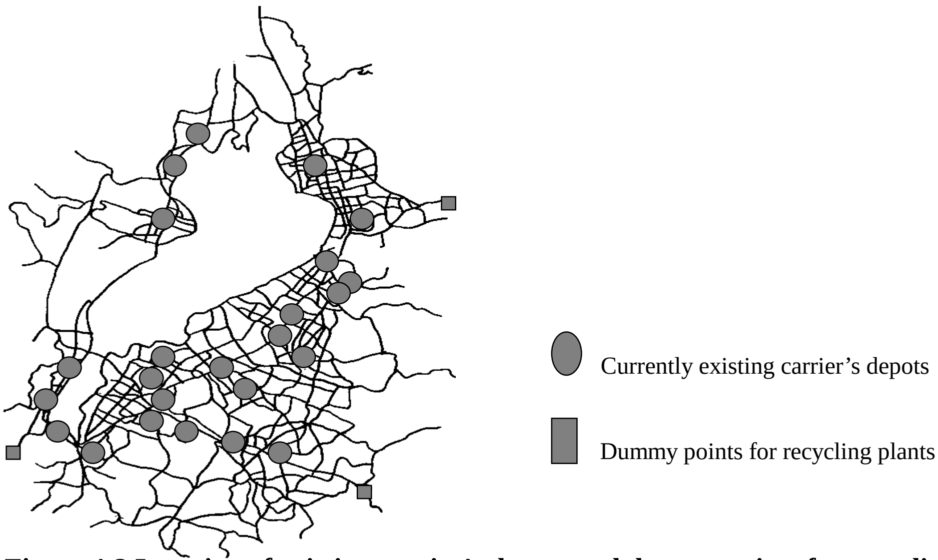


Figure 4-2 Location of existing carrier’s depots and dummy points for recycling

4.3 Case study

Following three case studies are examined:

(1) Case 1

In order to investigate the current situation, the current storage facilities for used electrical appliances are scrutinized and the total ton km ratio is analyzed. Currently there are six existing storage facilities for electrical appliances in Shiga prefecture (Figure4-3). However, since two storage facilities exist at close positions, 4 storage facilities are set in the simulation model.

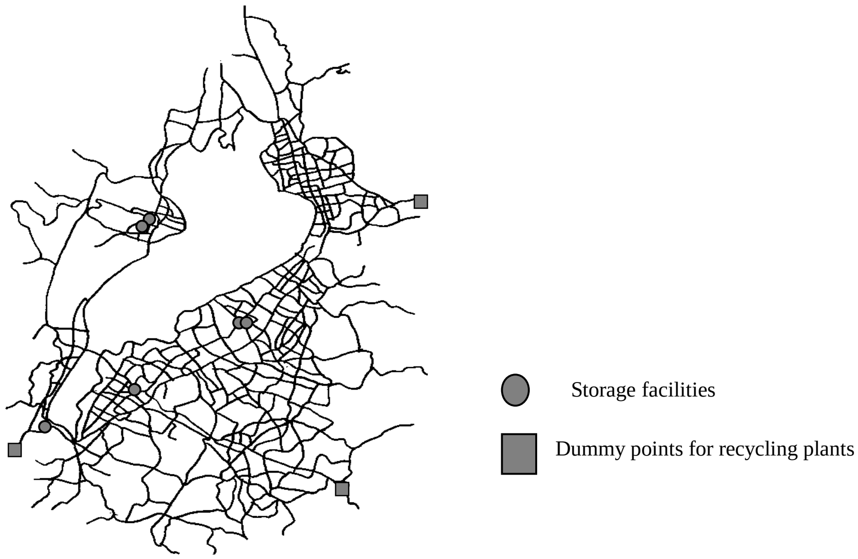


Figure 4-3 Current location of storage facilities for used electrical appliances

(2) Case 2

Depending on the number of storage facilities, storage facilities, which can minimize the total ton km ratio, are chosen from combinations of 27 major carrier's depots including six storage facilities.

(3) Case 3

Case 3 is based on case 2, and a constraint is also taken into account. There are thirty-eight autonomies in Shiga prefecture. Otsu city contains a large proportion of the prefecture's population (around 20%) and used electrical appliances. However, since it is located in the most urbanized zone in Shiga prefecture, storage facilities which can minimize total ton km are chosen from existing carrier's depots excepting those in Otsu city.

4.4 Results

4.4.1 Effects of the selection of optimum storage facilities

Figure 4-4 presents the effect of the proper positioning of storage facilities. There is not much difference noted between the data from collecting points to dummy points for recycling plants, and when the storage facilities are set to minimize total ton km, the reduction of the sum of all the ton km ratios do not depend on the number of storage facilities. On the other hand, the data from collecting points to storage facilities shows that the more storage facilities are introduced, the smaller the total ton km should be obtained. Also, the data from storage facilities to dummy points for recycling plants shows that the more storage facilities there are, the greater the total ton km obtained.

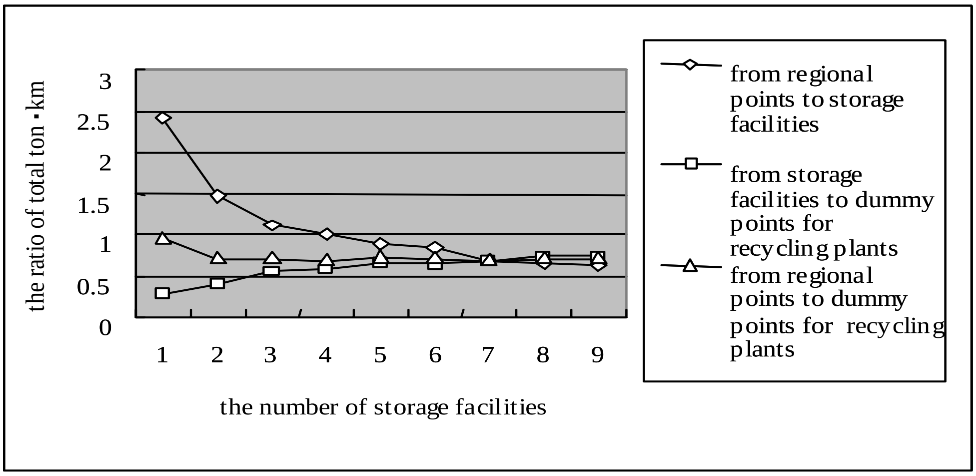


Figure 4-4 Index expression of effect of proper location of storage facilities based on current situation (case 1)

4.4.2 Effect of the selection of optimum storage facilities with a constraint.

In case 3, in most urbanized Otsu city, no storage facilities are set with the consideration of congestion and the difficulty of handling goods. Even though case 3 do not include any storage facilities in Otsu city, the total ton km ratio (case 3) becomes smaller than that produced in the current situation (case 1) (Figure4-5). Also, case 3 has the same type of graph as the introduction of case 2. However, compared with the optimum case taking into account all existing storage facilities (case 2), the reduction of the total ton km ratio does not make much change when the number of storage facilities is increased (Figure4-6).

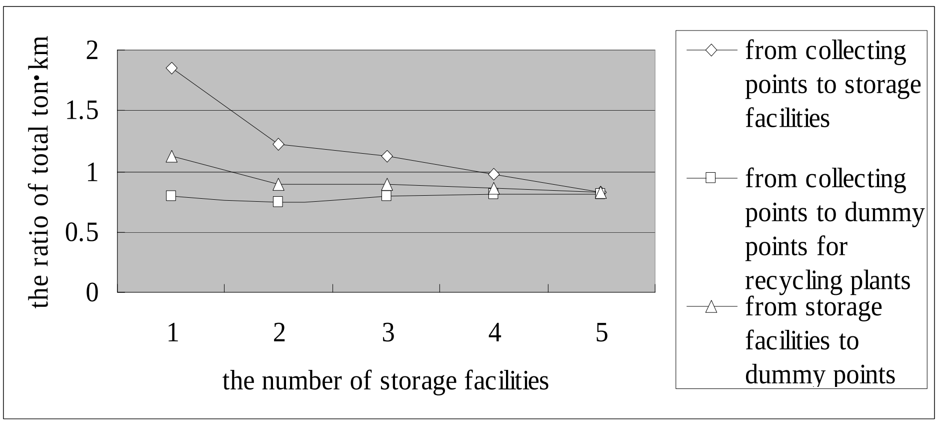


Figure 4-5 Index expression of effect of optimum location selection with a constraint based on current situation (case1) is fixed

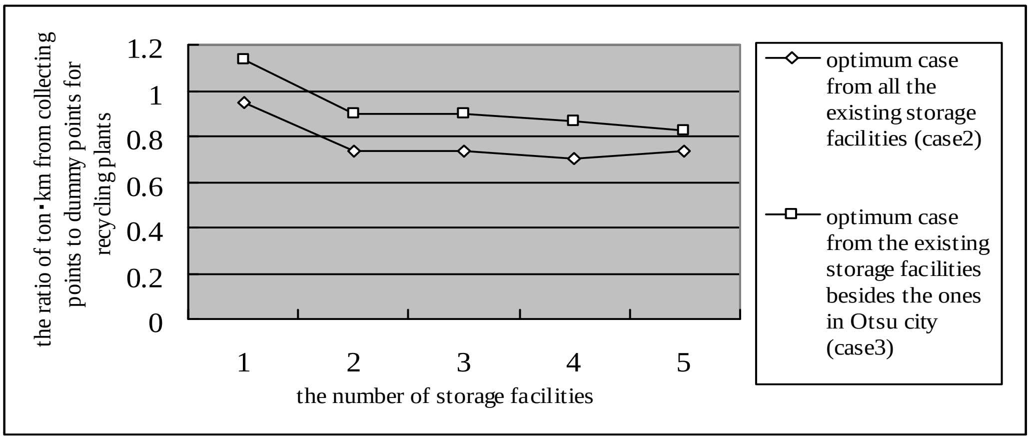


Figure 4-6 Index expression of comparison between case 2 and case 3 based on current situation

5. Conclusion

In Japan the governmental regulation for used electrical appliances started from year 2001. The amount of used electrical appliances from the autonomies is uncertain. Therefore, in this study, the yearly discharge of used electrical appliances is estimated from the yearly gross sales of electrical appliances and the ratio of disposal.

The selection of suitable storage facilities in terms of the minimization of the total ton km ratio is conducted, and three cases are applied. Case 1 calculates the total ton km applying the data from current storage facilities. In case 2, storage facilities, which have the least total ton km are chosen from all the existing facilities. Last of all, in case 3, the existing carrier's depots in Shiga prefecture except for the ones in Otsu city are applied and storage facilities which have the minimum total ton km are selected.

As a result, the total ton km from collecting points to recycling plants indicated by dummy points do not show much difference between the number of storage facilities, and it shows that seven or eight storage facilities are suitable for handling used electrical appliances in Shiga prefecture. However, when the number of storage facilities increases, the total ton km from collecting points to storage facilities decreases, and the total ton km from storage facilities to dummy points increases. This means that the increase in the number of storage facilities can bring benefit to the retailers, and on the other hand, in the view of manufacturers in charge of the freight from storage facilities to recycle plants, it gives them inefficiency.
In future study, the effective way to connect reverse logistics to forward logistics should be considered. For instance, the optimum location of second hand shops and the capacity and function of storage facilities have to be considered.

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