Verification Study on the Kitchen Garbage Processing System Design as Part of the Wastes Processing Rationalization in the Corporate Area of Local City*

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1. Background

In recent years, it comes closer the difficulties of the problems of resources preservation on earth, environmental load and the garbage reclaimed lands. With this background, it is necessary for us to find the direction which is for activating the situation related to waster process, and build up the effective waste disposal plant system. In this research, one methodology for processing or recycling the life garbage with the system construction plan model was described. Firstly, based on practical data, current garbage processing technology and system were studied. Secondly, the amounts of the waste were estimated by the model, and the garbage collection and transportation model was also built up. Through the verification study for Kusatsu-city, an effective design methodology for the life garbage processing system in a local city is shown as the conclusion of this research.

2. The introduction of the planning system for kitchen garbage processing

The kitchen garbage processing plan model built in this research is set to a plan period T, and about the kitchen garbage discharged in household system and enterprise system. Taking the assumption of recycling processing, we studied the construction patterns of different kinds of facilities, their scales and distributions, for the objective of minimizing the total cost during the plan period T.

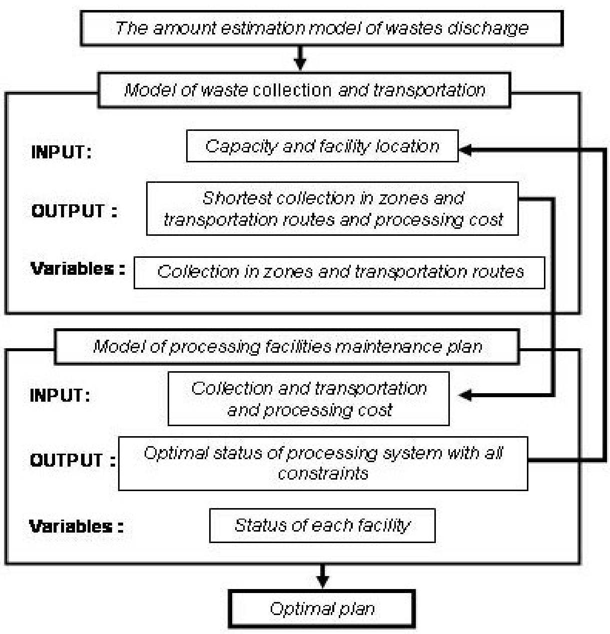

Figure 1: Concept of Planning System

The whole system included three models, describing the three plan stages. First the amount estimation model of waste discharge, which was developed by the team work before, calculated the amount of kitchen garbage of each plan year. Then in the model of waste collection and transportation, the estimation amount of waste was the constraint to be satisfied and each collection vehicle was assumed to get full volume and each facility was assumed to reach critical capacity. By this way, we set different facility location patterns as input, and by the second model, got the minimum cost for collection and transportation. The third model was the model of processing facilities construction plan. Having the collection and transportation and processing cost as the input, we concluded the optimal status of processing system with all constraints, described by the facility location and total capacity, and connected with the second model. The whole plan system included this cycle for each plan year.

The concept of the plan system was also expressed by the Figure 1.

*Keywords:recycle: kitchen garbage, waste processing, recycle

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3. Explanation of the two models

The amount estimation model of wastes discharge (household system)

$$W_{i\ house}^{re}(t) = \sum_{n \in N} q_{i\ house}^{n} \cdot S_{re}^{n}(t) \qquad ※N=5$$

$$q_{i\ house}^{n} = f(u_i) = \alpha_i \ln(u_i) + \beta_i$$

$$u_i = f'(c_{char}^{i}) = \alpha_i' \ln(c_{char}^{i}) + \beta_i'$$

$W_{i\ house}^{re}(t)$: The annual volume of waste i of period t in region re (t/year)

$q_{i\ house}^{n}$: The waste discharge unit of n people household (t/household number*year)

$S_{re}^{n}(t)$: The number of n people household in t period in region re

u_i : Streamlining consciousness level of residents at the time of discharging wa

c_{char}^{i} : The price for collecting one garbage pack (Yen)

$\alpha_i, \beta_i\ \alpha_i', \beta_i'$: Parameters

The amount estimation model of wastes discharge (industrial system)

$$W_{i\ ind}^{re}(t) = r_{comp}^{i} \cdot q_{i\ ind}^{e}(t) \cdot P_{re}(t)$$

$$q_{ind}^{e}(t) = \sum_{k \in K} \alpha_k (R_k^e(t)) + \beta$$

$W_{i\ ind}^{re}(t)$: The annual volume of waste i of period t in region re (t/year)

$q_{ind}^{e}(t)$: The industrial waste i discharge unit of period t in area e (t/year*people)

$P_{re}(t)$: The number of employees of period t in region re

r_{comp}^{i} : The rate of components of industrial waste i

$R_k^e(t)$: The rate of employee in industrial classification k during period t in are

α_k, β : Parameters of regression model

Model of waste collection and transportation

Objective

$$\sum_{i,j} c_{ij} \cdot \delta_{ij} \rightarrow \min \quad (i \neq j)$$

Subject to

$$\sum_{i \neq i'} \delta_{ij} = 1 \qquad \sum_{j \neq j'} \delta_{ij} = 1 \qquad i'\ j' \text{ :middle processing facilities}$$

$$\sum_{i \in I_z''} w_i \leq b' \qquad \sum_{i \in I_z} w_i^k \leq b_k \qquad u_i - u_j + n\delta_{ij} \leq n - 1$$

$$i, j = 0, 1, \cdots, n \ (i \prec j)$$

c_{ij} : Cost of collection and transportation from station i to j in zone

δ_{ij} : if route ij is chosen, it is 1,if not, it is 0

w_i : the waste discharge volume of station i

w_i^k : the waste volume into facility k

b' :Vehicles loading capacity (t/v)

b_k : critical capacity of facility k (t/da

u_i : the auxiliary variable of t when the vehicle arrives station i and counts t spots

n : The total amount of station in the zone

In January, 2002, our group carried out one survey around Kusatsu city about the discharge of household. As one of the public policies, payment for each collection is charged, which influences the discharge behavior of citizens. It was concluded that the logarithmic function was able to resemble the relationship between the price for collection and the streamlining consciousness level of residents to some exact extent. Then the household system model was built according to region, kinds of waste, period and the scale of the household.

The industrial system involved much more complex factors for waste discharge. It was necessary to discuss the industrial system from different aspects such as the situation of employment, industrial classification and industrial distribution in each region. By regression method, the formulation has been well completed.

In the model of collection and transportation, the basements of trucks, stations, capacity and average speed of vehicles, and the status of middle processing facilities which means the temporary store base of waste, were all given as factors. The cost of one distance unit included cost of workers' payment and fuel, and the transshipment fee. It was assumed that only one truck worked back and forth in one zone for eight hours a day and always selected the shortest route between stations. To make it convenient, we did not consider about the traffic conditions such as traffic congestion.

These three formulation models have been developed in the former researches and proved to be able to simulate the practical situation rationally. Then we apply them to the planning system.

4. Model of processing facilities construction

The functions above represent the model of processing facilities construction. In details, about the income:

- ✓ The processing industry: mainly from tax of the processing, not from the collection payment.
- ✓ The subsidy from national government: at most 50% of the construction free can be got from the subsidy.
- ✓ The sale of recycled resources: the product from the recycle processing.
- ✓ The commission fee of kitchen garbage collection: mainly refer to the payment of the bag garbage collection from residents.

In the plan model, we set the minimization of the total cost of plan period as the objective. At the same time, some constraints were established for the optimization, such as refund time, usage duration, capacity of each facility and bury volume limits. The following functions show the whole formulation model.

【Objective function】

$$\sum_{t=1}^{T} f(t) \quad ==> \quad Min \qquad (1)$$

【Constraints】

$$f(T) \leq 0 \quad \text{(Refund time)} \qquad (2)$$

$$T_s \leq T_l \quad \text{(Usage limits)} \qquad (3)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} w_i^j \leq wi_{\max}^j \quad \text{(Capacity)} \qquad (4)$$

$$\sum_{t=1}^{T} g(t) \leq G \quad \text{(Bury volume)} \qquad (5)$$

【Original conditions】

$$f(0) = 0 \qquad (6)$$

$$g(0) = 0 \qquad (7)$$

$$\chi(0) = \emptyset \qquad (8)$$

【Plan variables】

$\chi(t)$ = ｛ x *i1(t)*, x *i2(t)*,…., x *ij(t)*,…, x *IJ(t)*｝ (9)

If kind *i*, location *j* is built, x *ij(t)*=1, otherwise, x *ij(t)*=0

$f(t)$：total cost of period t

$$f(t) = h(t) + u(t) + s(t) + r(t) - c(t) \qquad (10)$$

$h(t)$: construction cost of period t (11)

$u(t)$: run cost of period t (12)

$s(t)$: collection and transportation cost of period *t*, output of the other models (13)

$c(t)$: income of processing kitchen garbage of period t (14)

$r(t)$: the interest of period t (15)

T_s : years of construction Tl: years of duration

$w_i^j(t)$: the input waste of period t in facility t and place j

$w_{i\max}^j$: the critical capacity for the input waste of period t in facility t and place j

$g(t)$: the volume of bury waste of each period

$$g(t) = \sum_{ij} w_i^j(t)\, \alpha_i^j(t)\, \theta(t)$$

$\alpha_i^j(t)$: the leaving ratio of facility *ij*

$\theta(t)$: The rate of loss in quantity for extraction reusable garbage

5. Analysis results

After model formulation, we collected data about Kusatsu city in Shiga prefecture, which contains six zones and was the subject city of this research. We listed five patterns as alternatives for the optimal proposal:

Pattern 1: new large scale facilities is set near to current cleaning center for dealing with kitchen garbage efficiently

Pattern 2: expansion of the current compost center in mountain area for dealing with kitchen garbage efficiently

Pattern 3: setting facilities for each zones, based on campus district unit

Pattern 4: improvement of pattern 3 considering the difficulties of many current streets

Pattern 5: improvement of pattern 4 with only two zones in the city

Cost for collection and transportation (Thousand *yen*/ year)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8	Period 9	Period 10
Pattern 1	136,916	136,985	137,053	137,122	137,190	137,259	137,328	137,396	137,465	137,534
Pattern 2	131,219	131,284	131,350	131,416	131,481	131,547	131,613	131,679	131,745	131,811
Pattern 3	96,869	96,917	96,966	97,014	97,063	97,111	97,160	97,208	97,257	97,306
Pattern 4	103,797	103,849	103,901	103,953	104,005	104,057	104,109	104,161	104,213	104,265
Pattern 5	117,766	117,825	117,884	117,943	118,002	118,061	118,120	118,179	118,238	118,297

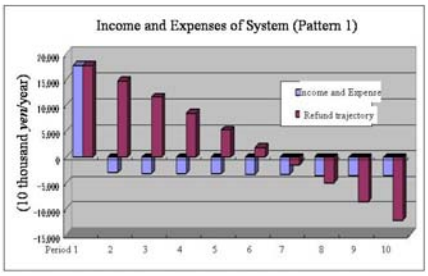
The figures in this part gave the estimated amount of the kitchen garbage and the cost for collection and transportation was then be calculated as the output of the first section in system.

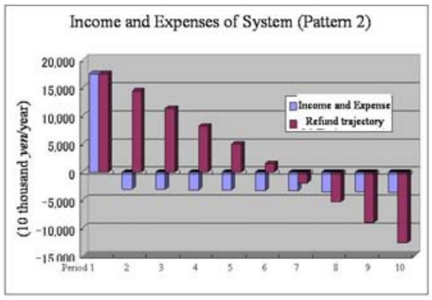
Household kitchen garbage (ton/year)

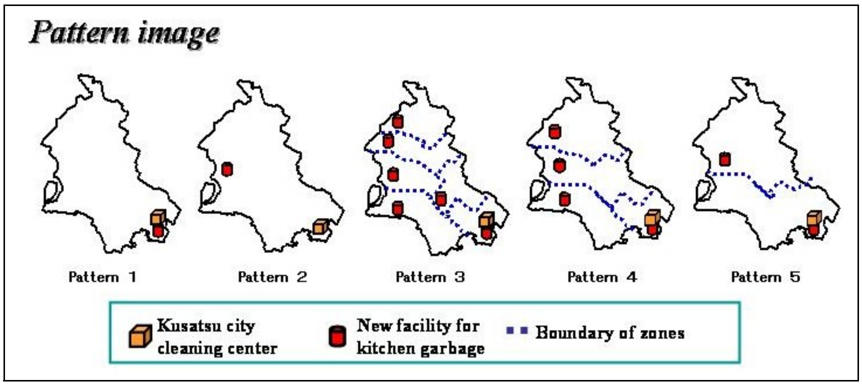
	1	2	3	4	5	6	7	8	9	10
志津	1234.3	1284.4	1308.3	1453.4	1513.5	1522.6	1532.5	1497.9	1512.0	1577.3
草津	3133.8	3001.0	2814.4	2878.8	2998.7	3019.5	3043.9	2979.5	3013.8	3151.5
老上	3007.9	2884.7	2708.5	2773.0	2891.0	2913.1	2931.9	2864.5	2890.2	3014.2
山田	665.4	640.81	603.5	619.4	646.9	652.5	659.8	646.2	654.0	684.3
笠縫	1939.4	1861.3	1747.1	1786.9	1859.9	1863.3	1868.2	1817.7	1843.8	1914.1
常盤	361.3	341.7	316.1	323.5	336.9	338.7	340.7	332.1	334.5	348.3

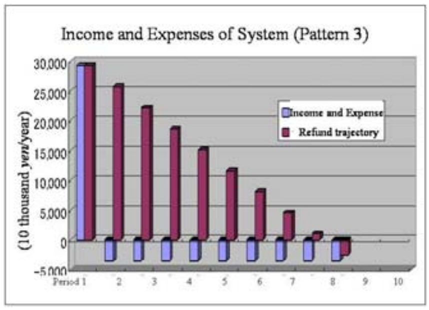
Industrial kitchen garbage (ton/year)

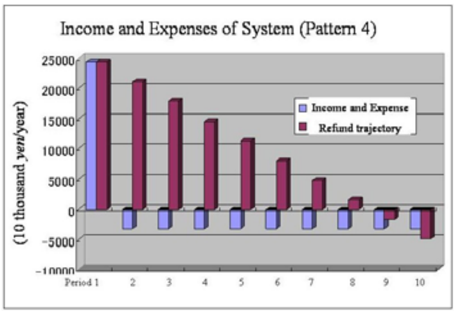
	1	2	3	4	5	6	7	8	9	10
志津	465.0	467.8	470.4	472.7	474.7	476.6	478.1	479.5	480.7	481.6
草津	1166.9	1170.7	1173.7	1176.1	1178.0	1179.2	1179.8	1179.9	1179.5	1178.5
老上	1065.1	1069.0	1072.2	1074.8	1076.9	1078.4	1079.4	1079.9	1079.9	1079.4
山田	144.6	147.5	150.4	153.2	155.9	158.5	161.0	163.4	165.8	168.1
笠縫	319.4	322.6	325.5	328.3	330.9	333.3	335.6	337.7	339.6	341.4
常盤	128.0	130.4	132.6	134.8	137.0	139.0	141.0	142.9	144.8	146.6

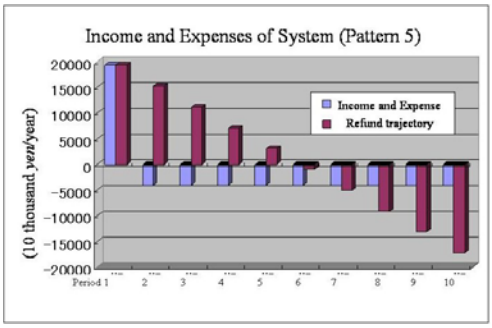


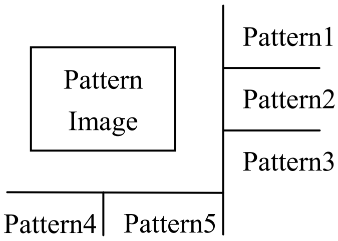












The five patterns were selected from the classification of area from city level, to zone level and to campus district level. Then they were put into the planning system for income and expense as output, which was the most important criterion for proposal selection regarding to the objective in this research.

6. Conclusion

Since considering the efficiency in a cost side the pattern 5, the pattern 2, and the pattern 3 have completed refund in a comparatively early stage, they were rational plans For a certain reason, generally, since the portion which cannot be evaluated only by the efficiency in a cost side also has the good efficiency of cost, it cannot be declared that it is a good plan, either. Moreover, since thoroughness of judgment does influence strong against quality in this system, the method which takes the classification of discharge person tends is to be advanced.

Reference

1) Tachibana Junzo, Study on Development of Model on Desirable Waste Disposal System in Regions, Doctoral Thesis, Ritsumeikan University, 2003