The Sixteenth International Symposium on Artificial Life and Robotics 2011 (AROB 16th '11),
B-Con Plaza, Beppu,Oita, Japan, January 27-29, 2011

Building of Reverse Logistics Model in Reusable Recovery and Optimization considering Transportation, Inventory, and Backorder Costs

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Abstract: This paper deals with the building of the reusable reverse logistics model considering the decision of the backorder or the next arrival of goods. The optimization method to minimize the transportation cost and to minimize the volume of the backorder or the next arrival of goods occurred by the Just in Time delivery of the final delivery stage between the manufacturer and the processing center is proposed. Through the optimization algorithms using the priority-based genetic algorithm and the hybrid genetic algorithm, the sub-optimal delivery routes are determined. Based on the case study of a distilling and sale company in Busan, Korea, the new reverse logistics model in reusable recovery of empty bottles is built and the effectiveness of the proposed method is verified.

Keywords: Reusable Recovery, Reverse Logistics, Backorder or Next arrival of Goods

I. INTRODUCTION

For achievement of the resources recycling society and the low carbon society, the reverse logistics which targets the flow from production recovery to reproduction of end of life products has been received attention in the logistics field. During tightening regulation on environment increasingly, the reverse logistics has been magnified by the following reasons: First, economic effect resulted from the cost reduction of raw materials in manufacturing process. Second, the propensity to consume changed to the environment-friendly product. Third, business strategy tried to improve the image of corporate.

However, the reverse logistics is different from the traditional forward logistics where new material or part are produced and sold to customer. In the reverse logistics, it is not only hard to predict the appearing time or amount of arrivals by the used periods or condition of the recovered products, but also the recovery routes are complex as there are lot of recovery centers. Moreover, even though the recovery products are environment-friendly, its market is not large yet because of the stereotype of customers who regard the recovery product as used goods. And the reverse logistics costs more than the traditional forward logistics to construct and operate the system.

There have been lots of researches on the remanufacturing recovery that processing operation is complex and the forms of products are various Jayaraman[1] represented the reverse logistics model of the Remanufacturing Recovery considering the delivery cost from the returning center to the processing center. And Tang[2] showed the reverse logistics model considering the disassembly process in the processing center. However, they haven't discussed the processing operation to clean and refill the recovered products. On the other hand, researchers[3] extended these models, and represented reverses logistics model of the remanufacturing recovery that the disassembling, cleaning, refilling operations were included in the processing center and the transportation cost from the returning center to the processing center, manufacturing plant is considered. Moreover, they have built the reverse logistics model considering that a reusable part is delivered to the manufacturer and a part to disposal. In additions, they have discussed the reverse logistics model considering the direct route to each processing operation in processing center, recycling center, manufacturing plant or disposal as the condition of recovered product in the returning center. And the remanufacturing reverse logistics model was built considered inventory cost before and behind each processing operation which the recovered product through the returning center.

Therefore, for optimizing the reverse logistics with uncertainty of amount or occurrence time of the recovery product, to build a model is necessary considering not only transportation cost but also the date and the processing of the decision whether waiting for arrival of an end-of-life product with the unclear amount to the returning center or backordering necessary parts for manufacturing.

In this paper, a reusable reverse logistics model considering the decision of backordering or waiting for the next arrival of goods on the base of the reusable recovery is built. And, the optimization method of the reusable recovery to minimize the transportation cost and the volume of the backorder or next arrival of goods occurred by the just in time delivery of the final delivery stage between the manufacturer and the processing center is described. In addition, this method can be also applied to the remanufacturing recovery and the recycling recovery.

II. BUILDING OF REUSABLE REVERSE LOGISTICS MODEL AND OPTIMIZATION CONSIDERING TRANSPORTATION, INVENTORY, AND BACKORDER COSTS

The reverse logistics model in newly building reusable recovery is considered the Just in Time delivery cost from the processing center to manufacturer included decision whether waiting for arrival of the end-of-life product or backordering necessary parts for manufacturing when the end-of-life product gathering goods to the processing center through the returning center is less than the demand of manufacturer.

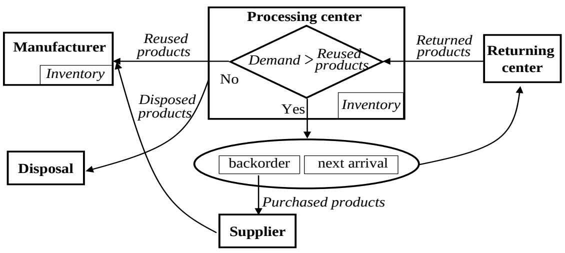


Fig. 1. Reusable reverse logistics model considering backorder or next arrival

Figure 1 describes the model combined the decision factors of the backordering or wait for the next arrival of goods based on the total inventory of the manufacturer in case of the end-of-life product gathering goods to the processing center through the returning center is less than the amount of demand.

Indices

i: returning center (i=1, 2, …, I ; I : number of returning centers)

j: processing center (j=1, 2, …, J ; J : number of processing centers)

t: time period (t=1, 2,…, T)

Parameters

a_i: capacity of the returning center i

b_j: capacity of the processing center j

d_K: capacity of the manufacturer K

$r_i(t)$: amount of the end-of-life product recovered to the returning center i

$d_K(t)$: demand of in the manufacturer K

u_K: amount of an upper limit of backorder of the manufacturer K

c^1_{ij}: unit cost of the transportation from the returning center i to the disassembly center j

c^2_{jK}: unit cost of the transportation from the processing center j to the manufacturer K

c^3_{jD}: unit cost of the transportation from the processing center j to the disposal D

c^4_{SK}: unit cost of the transportation from the supplier S to the manufacturer K

c^{op}_j: unit holding cost of the processing center j

c^{H1}_j: unit inventory cost per period at the processing center j

c^{H2}_K: unit inventory cost per period at the manufacturer k

Decision Variables

$x_{ij}(t)$: amount shipped from the returning center i to the processing center j in the period t

$x_{jK}(t)$: amount shipped from the processing center j to the manufacturer K in the period t

$x_{jD}(t)$: amount shipped from the processing center j to the disposal D in the period t

$x_{KB}(t)$: backorder amount of the manufacturer K at the period t

$y^H_j(t)$: inventory amount at the processing center j in the period t

$z^H_K(t)$: inventory amount at manufacturer K in the period t

$w_K(t)$: Binary variable equals 1 when the safety inventory is secured in manufacturer K and 0 when backorder is necessary

z_j: Binary variable equals 1 when processing center j is hold, otherwise 0.

Objective Function

Minimize the transportation cost, occurred backorder cost or inventory cost by the JIT delivery according to waiting for the next arrival of goods

$$
\begin{aligned}
f &= \alpha_1 f_1 + \alpha_2 f_2 \\
&= \alpha_1 \sum_{t=1}^{T}\left[\sum_{j=1}^{J} c_j^{op} z_j + \sum_{i=1}^{I}\sum_{j=1}^{J} c_{ij}^{1} x_{ij}(t) + \sum_{j=1}^{J} c_{jK}^{2} x_{jK}(t)\right] \\
&\quad + \alpha_2 \sum_{t=1}^{T}\left[c_{SK}^{4} x_{KB}(t) + c_K^{H2} z_K^{H}(t) + \sum_{j=1}^{J} c_{jD}^{3} x_{jD}(t) + \sum_{j=1}^{J} c_j^{H1} y_j^{H}(t)\right] \to \min
\end{aligned}
$$

$$\alpha_1, \alpha_2 : \text{weight} \qquad (1)$$

Subject to

The recovered amount of the end-of-life product:

$$\sum_{j=1}^{J} x_{ij}(t) \le r_i(t), \quad \forall i,\ t \tag{2}$$

Capacities of the processing center and manufacturer:

$$\sum_{i=1}^{I} x_{ij}(t) + y_j^{\mathrm{H}}(t-1) \le b_j z_j, \quad \forall j,\ t \tag{3}$$

$$\sum_{j=1}^{J} x_{jK}(t) + y_K^{\mathrm{H}}(t-1) + x_{KB}(t) \le e_K, \quad \forall t \tag{4}$$

The amount of the backorder when selecting the backorder:

$$d_K(t) - z_K^{\mathrm{H}}(t-1) - \sum_{j=1}^{J} x_{jK}(t) = x_{KB}(t), \quad \forall\ t \tag{5}$$

The inventories of the processing center and manufacturer:

$$y_j^{\mathrm{H}}(t-1) + \sum_{i=1}^{I} x_{ij}(t) - (x_{jK}(t) + x_{jD}(t)) = y_j^{\mathrm{H}}(t), \quad \forall j,\ t \tag{6}$$

$$\sum_{j=1}^{J} x_{jK}(t) + z_K^{\mathrm{H}}(t-1) - d_K(t) = z_K^{\mathrm{H}}(t), \quad \forall\ t \tag{7}$$

The restriction not to be able to execute waiting of arrival of goods and relapse note at the same time in the processing center:

$$z_K^{\mathrm{H}}(t) \le u_K w_K(t), \quad \forall\ t \tag{8}$$

$$x_{KB}(t) \le u_K(1 - w_K(t)), \quad \forall\ t \tag{9}$$

Non-negativity of the decision variables:

$$x_{ij}(t),\ x_{jK}(t),\ x_{jD}(t), x_{KB}(t) \ge 0,\ \ \forall i,\ j,\ t \tag{10}$$

Decision variable of the holding determination:

$$z_j \in \{0,1\} \quad \forall j \tag{11}$$

The reverse logistics is formulated as a mixed integer programming problem, and is one of the NP-hard problems. The mixed integer programming problem with comparatively little integer variable is possible to be solved in practicable time using traditional optimization software. But it becomes impossible to be applied for the large-scaled problem in this research since the calculating time or using memory increase geometrically. Therefore, the sub-optimal solution is calculated using GA as the solution of this problem.

III. OPTIMIZATION OF REUSABLE REVERSE LOGISTICS USING GENETIC ALGORITHM

1. Priority based genetic representation

Encoding: The chromosome with length which is totalized by returning center (I) and processing center (J) is generated. The value of each gene represents the priority and an initial value allocated by the priority starts from total of the gene, (I+J). Then the priority 1 less than the selected gene randomly is allocated till every gene has the priority value. For example, two chromosomes with the total of returning centers, I=5 and total of processing centers, J=3, the capacities of the returning center and the processing center and the transportation cost from the returning center to the processing center are shown in the Figure 2.

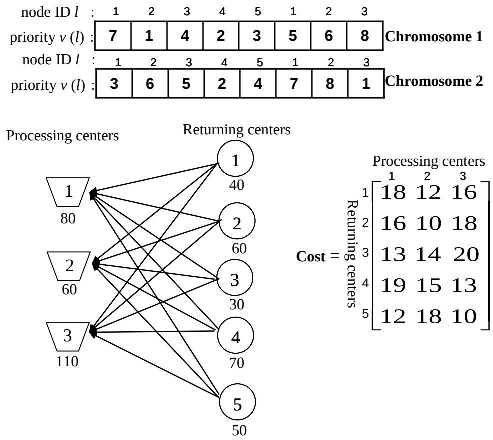


Fig. 2. Example of Representation for Chromosome

Decoding: In case of the first chromosome, the lowest cost of returning center for processing center with the highest priority is the returning center 5. The shipments (50) are decided by the maximum deliveries (50, 110). Moreover, the returning center 4 with the second lowest transportation cost is selected for the processing center 3. The Shipments (60) are decided by the maximum deliveries (70, 60). Since the capacity 110 in the processing center 3 was satisfied, the priority is reset to 0, and the returning center 1 with the second highest priority is selected.

2. Genetic operators

The WMX crossover determines a cutting point randomly and generates an offspring exchanging the right parts of the chromosomes from the cutting point. The exchanged right parts are arranged by each ascending orders. Next, the numbers of genes that become a pair to each other are checked and changed by the relationship. The Swap mutation [4] selects randomly the pairs of the gene exchanged in eight genes and exchanges the selected genes.

3. Optimization by priority-based Genetic Algorithm

Priority-based genetic representation adopted for the chromosome representation is used to show the node of the gene position and the value is used to show the priority of the node.

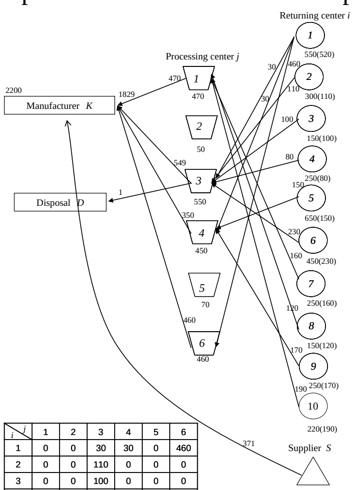
4. Optimization by hybrid Genetic Algorithm

Besides the function of priGA, hGA improves the searching ability of GA through adjusting the parameter appropriately in each generation using FLC [4] and making a suitable situation by the optimal solution search.

IV. SIMUTAION AND RESULTS

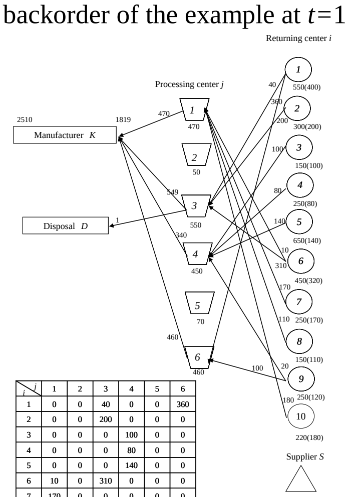
1. Numerical example

This paper considers the ten returning centers and the six processing centers, the manufacturer, the disposal and one each supplier. In the Figures 3 and 4, the sub-optimal delivery route and the amount of backorder in period t1 and t2 are shown respectively.



i \ *j*	1	2	3	4	5	6
1	0	0	30	30	0	460
2	0	0	110	0	0	0
3	0	0	100	0	0	0
4	0	0	80	0	0	0
5	0	0	0	150	0	0
6	0	0	230	0	0	0
7	160	0	0	0	0	0
8	120	0	0	0	0	0
9	0	0	0	170	0	0
10	190	0	0	0	0	0
Amount of backorder in t=1: 371						

Fig. 3 Sub-optimal delivery routes and amount of backorder of the example at t=1



i \ *j*	1	2	3	4	5	6
1	0	0	40	0	0	360
2	0	0	200	0	0	0
3	0	0	0	100	0	0
4	0	0	0	80	0	0
5	0	0	0	140	0	0
6	10	0	310	0	0	0
7	170	0	0	0	0	0
8	110	0	0	0	0	0
9	0	0	0	20	0	100
10	180	0	0	0	0	0
Amount of backorder in t=2: 0						
Amount of inventory in t=2: 1819						

Fig. 4 Sub-optimal delivery routes of the example at t=2

This minimum costs 1,290,220 includes the transportation cost of from the returning center to processing center, the holding cost of the processing center, the transportation cost from the processing center to the manufacturer, the inventory cost of the processing center and the manufacturer, the backorder cost of the supplier and the disposal cost. Neither processing centers 2 and 5 are selected nor is holding cost reduced.

2. Case of Bottle reusable reverse logistics of distilling and Sale Company

The optimization problem of the bottle reusable recovery case with a distilling and sale company in Busan, Korea by the real data was simulated. It set to 20 of the population size, 0.7 of the initial WMX crossover rate, 0.3 of the initial mutation rate, and 5000 of the maximum generation as a simulation condition of the proposed method. The minimum costs of the priGA and hGA are 3,975,048 and 3,963,330 respectively. Figure 5 shows the sub-optimal delivery routes and the selected situation of the returning center. In this sub-optimal delivery routes, the five recovery centers (dotted circle in the Figure 5 are removed because of these high holding cost. The total of variables in this case study is 22435, and it is impossible that the traditional optimization software LINGO calculates the solution in practicable time. However, the priGA and hGA could calculate the solution in the practicable time, 6.42[sec] and 4.45[sec], respectively.

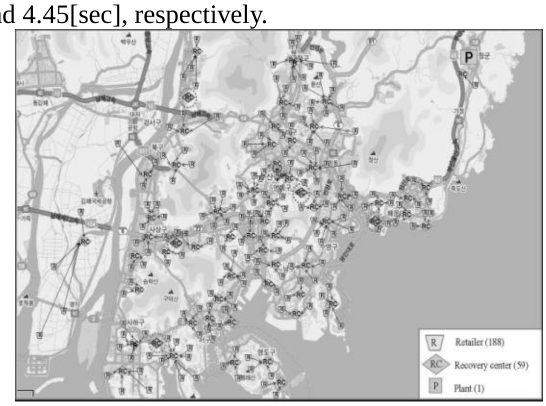


Fig. 5 Sub-optimal delivery routes and selected or unselected recovery centers

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