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INTEGRATED FORWARD AND REVERSE LOGISTICS MODEL: A CASE STUDY IN DISTILLING AND SALE COMPANY IN KOREA

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Abstract. *This paper aims to build integrated forward and reverse logistics model, and to optimize it with closed loop supply chain (CLSC). After that, we evaluate the effectiveness of the proposed model with the numerical examples, and simulate it with a bottles distilling/sale company in Korea. This paper designs the method of calculation for a solution using optimization algorithms with the priority-based genetic algorithm (priGA), and the hybrid genetic algorithm (hGA) by Fuzzy Logic Control (FLC). We describe the effectiveness of hGA such as shortness of computation time and better solutions with comparing experimental results with by ones of a conventional priGA and hGA. We determine the optimal delivery routes, and discuss its results on open and integrated facilities through a simulation. Based on the case study of a distilling and sale company in Busan, Korea, the new model of closed loop supply chain of bottles is built and the effectiveness of the proposed method is verified. In closed loop supply chain, bottles produced from plant are transported to retailer through DC. In retailer, product and end-of-life product are treated in the same time. We find that the total cost related with the forward, reverse, and closed loop supply chain model can be reduced by integrating forward and reverse flow with Lingo, priGA and hGA. The value of this paper is summarized as follows.*

- *The optimization method of the closed loop supply chain to minimize the transportation cost, inventory cost, open cost, purchasing cost and disposal cost is proposed.*
- *This paper presents calculation method of solution using optimization algorithms of the priority-based genetic algorithm (priGA) and the hybrid genetic algorithm (hGA) by Fuzzy Logic Control (FLC).*
- *In the experimental results comparing conventional priGA and hGA, we demonstrated the effectiveness of hGA such as shortness of computation time and better solutions.*
- *Through the simulation, the optimal delivery routes and the open and integration results of facilities are determined.*
- *Based on case study using real data for the reusable reverse logistics problem from a distilling and sale company, the effectiveness of the proposed method was improved.*

Finally, we could compare of GA to other meta-heuristics such as simulated annealing, and Tabu search methods are worth investigating in future studies.

Keywords: Closed-loop supply chain, Forward/reverse logistics, Genetic algorithm (GA), LINGO

1. **Introduction.** In a recent decade, social demands for eco-friendly society have increased [1]. Many countries are getting interested in reverse logistics, because they consider it as a solution to accomplish eco-friendly society. Additionally, enterprises have recognized that logistics problems should be solved not only by reducing cost, but also by considering such social demands with an eco-friendly logistics. Forward logistics is to

focus on a traditional goods flow that includes production, delivery, distribution, and sale. However, reverse logistics covers returned goods, its collection, repair, resale, recycling, reuse, disposal, and comes to integrate each activities. Reverse logistics (RL) handles the flow from recovering products to reproducing end-of-life products. Therefore, reverse logistics can be an alternative to fulfill eco-friendly society. To achieve this goal, it is necessary to change an inclination of idea from on efficiency of SCM to on protection of resource, and on reduction of carbon dioxide [2]. The studies on reverse logistics have been conducted in related fields, such as Supply Chain Management (SCM), Material Requirement Planning (MRP), and Enterprise Resource Planning (ERP) [3]. Reverse logistics is implemented with Closed-Loop Supply Chain (CLSC) that has described a forward logistics [4]. CLSC depicts both a forward flow from supply parts and a reverse flow from return parts. This paper aims to build integrated forward and reverse logistics model, and to optimize it with closed loop supply chain (CLSC). After that, we evaluate the effectiveness of the proposed model with the numerical examples, and simulate it with a bottles distilling/sale company in Korea. Through a simulation, we determine the optimal delivery routes, and discuss its results on open and integrated facilities. This paper is organized as follows. We conducted literature review in Section 2. In Section 3, we define problems with mathematical formulation, assumptions, and notations of our model. In Section 4, we describe the priority-based genetic algorithm, and the hybrid genetic algorithm. Results of simulation for numerical examples and case study are discussed in Section 5. Finally, we discuss the conclusions in the final section.

2. **Literature Review.** One major issue in reverse logistics field is the integration of forward and reverse supply chain. It is necessary to integrate information with forward supply chain to achieve optimum planning and reduction of costs. The whole network for a supply chain should be designed to support for forward and reverse logistics efficiently [5]. The issues on closed loop supply chain (CLSC) have been explored with different case studies in previous literatures. Kannan et al. proposed a closed loop mixed integer linear programming model to determine the raw material level, production level, distribution and inventory level, and recycling level at different facilities with the objective of minimizing the total supply chain costs [5]. And, the model is solved by the proposed heuristics based genetic algorithm (GA). Min et al. presented a nonlinear integer program sorting the multi echelon, multi commodity closed loop network design problem involving product returns [6]. However, their models did not consider temporal consolidation issues in a multiple planning horizon. Min et al. proposed a mixed-integer nonlinear programming model and a genetic algorithm for its solution that could solve the reverse logistics problem involving consolidation of returned products in a CLSC [7]. Zhao et al. and Lindu et al. investigate the complicated supply chain, a closed-loop supply chain network is studied, which consists of a single supplier, multiple demand markets, many retailers and one third party logistics (TPL) entity in every market [8,9]. Sheu et al. presented a multi-objective linear programming model to optimize the operations of a green supply chain, integrated of forward and reverse logistics, including decisions pertaining to shipment and inventory [10]. Factors such as the used-product return ratio of raw material and corresponding subsidies from governmental organization for reverse logistics were considered in the model formulation. The authors al so proposed a real world case study for a Taiwan based notebook computer manufacturer. Fleischmann et al. presented a reverse logistics network design problem in the CLSC. They considered the both forward and reverse flow, allowing the simultaneous definition of the optimal distribution and recovery networks [11]. A MILP formulation was proposed that constitutes an extension of the traditional warehouse location problem. Extending Fleischmann et al.'s model, Salema et

al. proposed a generalized model for the design of reverse logistics [12]. However, when suspending the logistics between dismantlers and plants, both Fleischmann et al. and Salema et al.'s models did not consider the supplier side and lacked the relations between forward and reverse flows. Sometimes, the retailers also play the role of the returning centers. Thus, the capacity of retailer is used for both distribution and return. When the amounts of the collection are larger, then the amounts of the distribution must decrease under the same capacity. Similarly, if we consider the supply side, the plants must allow the materials flow from both forward and reverse under the same capacity. If the amounts of returns are larger in a certain plant, the amounts of orders from suppliers will decrease [13].

3. Problem Definition.

3.1. Model description. In this paper, we focus on a single product closed loop supply chain that includes the following separate operations: (i) forward flows, and (ii) reverse chain flows. The former is used to produce and deliver products to end-users, whereas the latter is used for recycling or waste-disposal of the same products. The network is structured as a typical 5-layer forward supply chain, namely: (i) supplier, (ii) manufacturer, (iii) distribution centers, (iv) retailers, (v) customers. And, a 4-layer structure is considered for a reverse supply chain, including: (i) returning centers, (ii) processing center, (iii) manufacturer (remanufacturer), (iv) disposal center. To build the closed loop supply chain model, I manufacturer, J distribution centers (DCs), K retailers, L customers, K' returning centers, M processing centers, and one disposal are assumed. Each processing center recovers end-of-life product from K' returning centers, and ships to manufacturer through processing in the processing process, the test process, and the disposal process. Figure 1 describes the model forward flow and reverse flow included saving from integrating retailer and returning center. Figure 2 shows the reverse logistics model of the reusable recovery included this method.

3.2. Assumptions. The mathematical models in this paper have the following assumptions:

A1. Based on the prediction and performance of the previous day, the demand is forecasted as following.

Prediction of the day = prediction of previous day + $\alpha\times$ (performance of previous day − prediction of previous day)

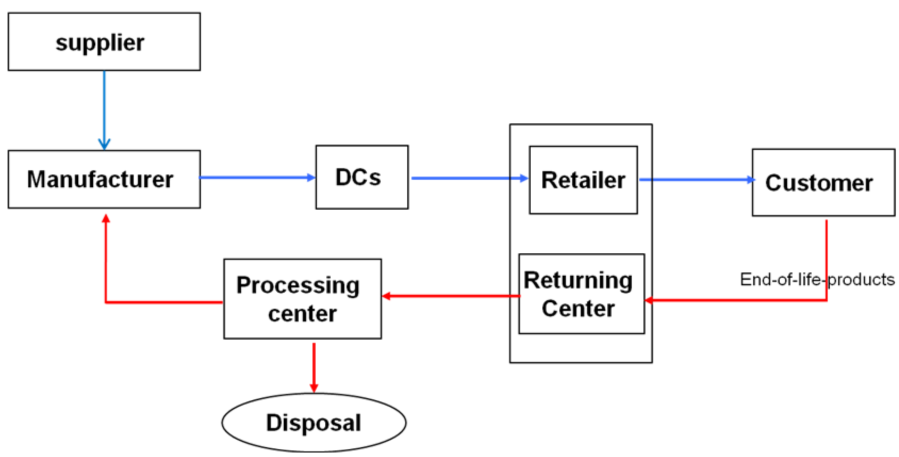

FIGURE 1. Integrated forward and reverse logistics model in a close loop supply chain

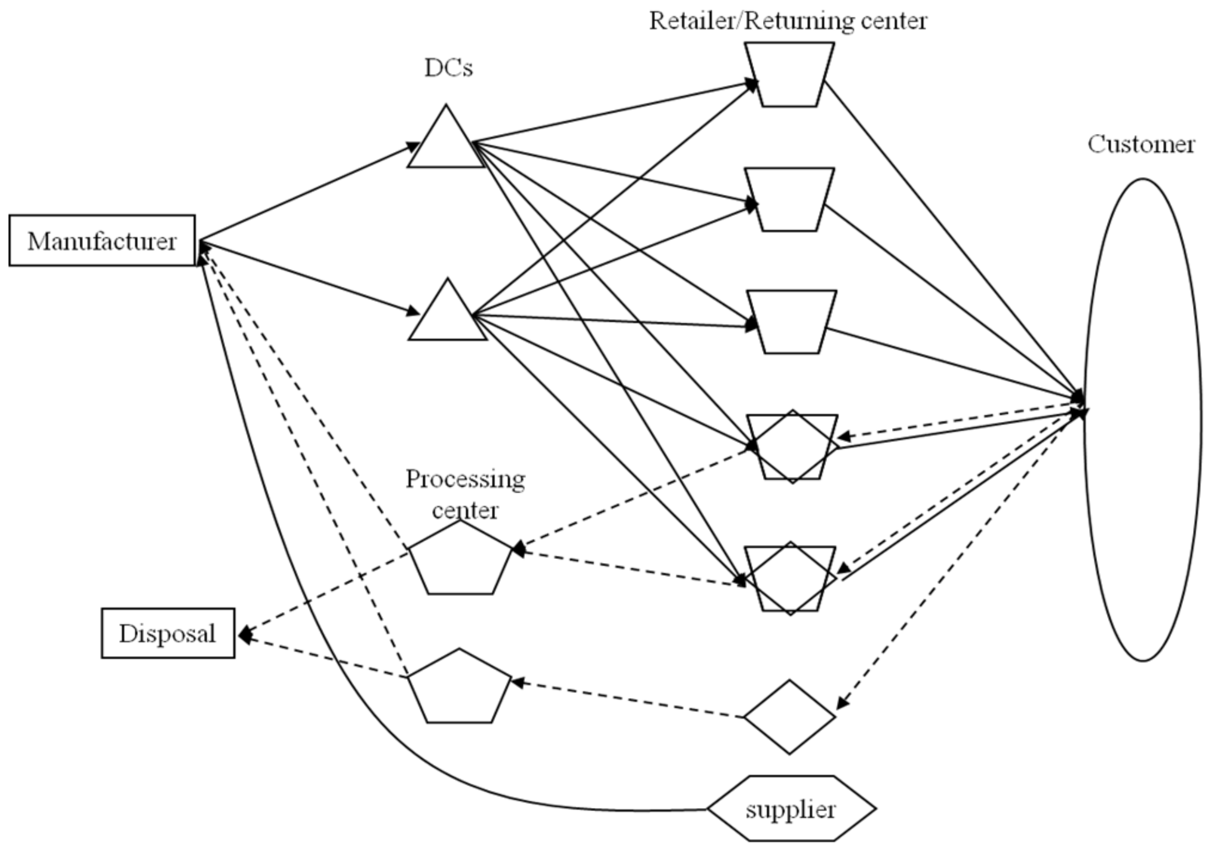

FIGURE 2. Closed loop supply chain model

A2. We consider the inventory factor at DCs, retailer, returning center, processing center over finite planning horizons to approach more real problem.

A3. The maximum capacities about six echelons are known: manufacturer, DCs, retailers, customers, returning centers and processing centers.

A4. Customers' locations are known.

A5. Costs parameters are known for each location and time period.

3.3. **Notations.** The parameters, the decision variables, the objective function, and the restriction in this closed loop supply chain model are as follows.

- Indies

i: index of manufacturer $(i = 1, 2, \ldots, I)$
j: index of distribution center $(j = 1, 2, \ldots, J)$
k: index of retailer $(k = 1, 2, \ldots, K)$
l: index of customer $(l = 1, 2, \ldots, L)$
k': index for returning center $(k' = 1, 2, \ldots, K')$
m: index of processing center $(m = 1, 2, \ldots, M)$
t: index of time period $(t = 1, 2, \ldots, T)$

- Parameters

I: number of manufacturers
J: number of distribution centers
K: number of retailers
L: number of customers
K': number of returning centers
M: number of processing centers

N: disposal center
S: supplier
T: planning horizons
a_i: capacity of manufacturer i
b_j: capacity of distribution center j
u_k: capacity of retailer k
$u_{k'}$: capacity of returning center k'
u_m: capacity of processing center m
d_i: demand of manufacturer i
c_{ij}^1: unit cost of transportation from manufacturer i to distribution center j
c_{jk}^2: unit cost of transportation from distribution center j to retailer k
c_{kl}^3: unit cost of transportation from retailer k to customer l
$c_{lk'}^4$: unit cost of transportation from customer l to returning center k'
$c_{k'm}^5$: unit cost of transportation from returning center k' to processing center m
c_{mN}^6: unit cost of transportation from processing center m to disposal N
c_{mi}^7: unit cost of transportation from processing center m to manufacturer i
c_{Si}^8: unit cost of transportation from supplier S to manufacturer i
c_j^O: open cost of distribution center j
c_k^O: open cost of retailer k
$c_{k'}^O$: open cost of returning center k'
c_j^H: unit holding cost of inventory per period at distribution center j
c_k^H: unit holding cost of inventory per period at retailer k
$c_{k'}^H$: unit holding cost of inventory per period at returning center k'
c_m^H: unit holding cost of inventory per period at processing center m
r_N: disposal rate

- Decision variables

$x_{ij}^1(t)$: amount shipped from manufacturer i to distribution center j in period t
$x_{jk}^2(t)$: amount shipped from distribution center j to retailer k in period t
$x_{kl}^3(t)$: amount shipped from retailer k to customer l in period t
$x_{ik'}^4(t)$: amount shipped from customer l to returning center k' in period t
$x_{k'm}^5(t)$: amount shipped from returning center k' to processing center m in period t
$x_{mN}^6(t)$: amount shipped from processing center m to disposal N in period t
$x_{mi}^7(t)$: amount shipped from processing center m to manufacturer i in period t
$x_{Si}^8(t)$: amount shipped from supplier S to manufacturer i in period t
$y_j(t)$: inventory amount at distribution center j in period t
$y_k(t)$: inventory amount at retailer k in period t
$y_{k'}(t)$: inventory amount at returning center k' in period t
$y_m(t)$: inventory amount at processing center m in period t

$$z_j(t) = \begin{cases} 1, & \text{if distribution center } j \text{ is opened} \\ 0, & \text{otherwise} \end{cases}$$

$$z_k(t) = \begin{cases} 1, & \text{if retailer } k \text{ is opened} \\ 0, & \text{otherwise} \end{cases}$$

$$z_{k'}(t) = \begin{cases} 1, & \text{if returning center } k' \text{ is opened} \\ 0, & \text{otherwise} \end{cases}$$

3.4. **Mathematical formulation.**

3.4.1. *Objective function.* The objective of the closed loop supply chain model is to minimize the total cost of the forward/reverse flow.

Minimize = Forward flows + Reverse flows
Forward flows = transportation costs + open costs + inventory costs + purchase cost
Reverse flows = transportation costs + inventory costs + disposal costs
− saving from integrating retailer/returning center (open costs)

$$
\begin{aligned}
\min z = \sum_{t=0}^{T} \Bigg[& \sum_{i=1}^{I}\sum_{j=1}^{J} c_{ij}^{1} x_{ij}^{1}(t) + \sum_{j=1}^{J}\sum_{k=1}^{K} c_{jk}^{2} x_{jk}^{2}(t) + \sum_{k=1}^{K}\sum_{l=1}^{L} c_{kl}^{3} x_{kl}^{3}(t) + \sum_{i=1}^{I} c_{Si}^{8} x_{Si}^{8}(t) \\
& + \sum_{j=1}^{J} c_{j}^{\mathrm{O}} z_j(t) + \sum_{k=1}^{K} c_{k}^{\mathrm{O}} z_k(t) - \sum_{k=1}^{K}\sum_{k'=1}^{K'} c_{k}^{\mathrm{O}} z_k(t) z_{k'}(t) + \sum_{k'=1}^{K'} c_{k'}^{O} z_{k'}(t) \\
& + \sum_{j=1}^{J}\sum_{k=1}^{K} c_{j}^{\mathrm{H}} y_j(t) + \sum_{k=1}^{K}\sum_{l=1}^{L} c_{k}^{\mathrm{H}} y_k(t) + \sum_{k'=1}^{K'}\sum_{m=1}^{M} c_{k'}^{\mathrm{H}} y_{k'}(t) \\
& + \sum_{l=1}^{L}\sum_{k'=1}^{K'} c_{lk'}^{4} x_{lk'}^{4}(t) + \sum_{k'=1}^{K'}\sum_{m=1}^{M} c_{k'm}^{5} x_{k'm}^{5}(t) + \sum_{m=1}^{M} c_{mN}^{6} x_{mN}^{6}(t) \\
& + \sum_{m=1}^{M}\sum_{i=1}^{I} c_{mi}^{7} x_{mi}^{7}(t) + \sum_{m=1}^{M}\sum_{i=1}^{I} c_{m}^{\mathrm{H}} y_m(t) \Bigg]
\end{aligned} \tag{1}
$$

where the objective function is to minimize the total logistics cost, including the amount dependent forward transportation cost (the 1st, 2nd, 3rd terms) and reverse transportation cost (the 12th, 13th, 15th terms), the purchase cost (the 4th term), the open cost of DCs, retailers and returning centers (the 5th, 6th, 7th, 8th terms), the inventory cost (the 9th, 10th, 11th terms and last term), the disposal cost (the 14th term).

3.4.2. *Constraints.*

— open costs

$$1 - z_j(t-1) = z_j(t) \quad \forall j \in J, \quad t \in T \tag{2}$$

$$1 - z_k(t-1) = z_k(t) \quad \forall k \in K, \quad t \in T \tag{3}$$

— inventory costs

$$y_j(t) = x_{ij}^{1}(t) + x_{jk}^{2}(t-1) \quad \forall j \in J, \quad t \in T \tag{4}$$

$$y_k(t) + y_{k'}(t) = x_{jk}^{2}(t) + x_{kl}^{3}(t-1) + x_{ik'}^{4}(t) + x_{k'm}^{5}(t-1) \quad \forall k \in K, \quad k' \in K', \quad t \in T \tag{5}$$

$$y_m(t) = x_{k'm}^{5}(t) + x_{mi}^{7}(t-1) - x_{mN}^{6}(t) \quad \forall m \in M, \quad t \in T \tag{6}$$

— disposal costs

$$\sum_{m=1}^{M} x_{mN}^{6}(t) = \sum_{k'=1}^{K'}\sum_{m=1}^{M} x_{k'm}^{5}(t) r_N \quad \forall t \in T \tag{7}$$

— capacity constraints

$$\sum_{j=1}^{J} x_{ij}^{1}(t) \le a_i \quad \forall i \in I, \quad t \in T \tag{8}$$

$$\sum_{k=1}^{K} x_{jk}^{2}(t) + y_j(t-1) \le b_j z_j(t) \quad \forall j \in J, \quad t \in T \tag{9}$$

$$\sum_{l=1}^{L} x_{kl}^{3}(t) + y_k(t-1) + \sum_{m=1}^{M} x_{k'm}^{5}(t) + y_{k'}(t-1) \le u_k z_k(t) + u_{k'} z_{k'}(t)$$
$$\forall k \in K, \quad k' \in K', \quad t \in T \quad (10)$$

— demand constraints

$$x_{mi}^{7}(t) + x_{Si}^{8}(t) + x_{ij}^{1}(t) = d_i \quad \forall t \in T \quad (11)$$

— non-negativity constraints

$$x_{ij}^{1}(t), x_{jk}^{2}(t), x_{ij}^{3}(t), x_{lk'}^{4}(t), x_{k'm}^{5}(t), x_{mN}^{6}(t), x_{mi}^{7}(t), x_{Si}^{8}(t) \ge 0$$
$$\forall i \in I, j \in J, k \in K, l \in L, m \in M, t \in T \quad (12)$$

— binary constraints

$$z_j(t) = \{0, 1\} \quad \forall j \in J, \quad t \in T \quad (13)$$
$$z_k(t) = \{0, 1\} \quad \forall k \in K, \quad t \in T \quad (14)$$
$$z_{k'}(t) = \{0, 1\} \quad \forall k' \in K', \quad t \in T \quad (15)$$

When the open cost of the facility is high, it is more effective to deliver the product to other facility without using this facility. As a result, the uselessness for open the facility with the high open cost can be lost and the all cost can be reduced. And, in this model, facilities open cost according to integration of the retailer/returning center is also reduced. To find the good feasible alternative, we attempts to solve the model described in proposed model using a genetic algorithm (GA) comprised of multiple steps of heuristics procedures, since a closed-loop supply chain network design belongs to a class of NP-hard problem [7].

4. **Optimization Closed Loop Supply Chain Using Genetic Algorithm.** Genetic algorithm (GA), one of the multi-point searching methods, is known to be effective, and the chromosome representation design is one of the important factors in the optimization approach using genetic algorithm. Genetic Algorithm is a commonly used optimizing tool for engineering calculation. It was proposed by Professor John Holland of the University of Michigan in 1975. Dengiz et al. offered many examples on GA, which showed that it can be applied to a wide variety of applicative domains [14]. For the fundaments of GA, one can refer to Gen and Cheng [15]. In the reverse logistics, Min et al. also successfully used GA to develop a multi-echelon reverse logistics network for product returns [16]. The concept of applying a priority-based encoding to supply chain network problems was proposed by Gen et al. [17].

In this paper, priority-based genetic algorithm (priGA) proposed by Gen et al. [18] is used for designing the chromosome and the optimization approach of the closed loop supply chain based on the priority based genetic representation is adopted.

4.1. **Optimization by priGA (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. Figure 3 shows the procedure of priGA.

4.2. **Optimization by hGA (hybrid genetic algorithm).** The genetic strategy parameter is fixed generally in the genetic algorithm and the evolution is processed based on the value. However, this method could lose the variety for the evolving process due to always repeating crossover and the mutation with the same probability. It is expected that the quality of the solution is not only improved but also the calculation time of

```
procedure: priGA for closed loop supply chain model
input: data set, GA parameters (popSize, maxGen, p_M, p_C)
output: the best solutions E
begin
  t ←0;
initialize P(t) by priGA encoding routine;
  evaluate P(t) by priGA decoding routine;
  while (not terminating condition) do
        create C(t) from P(t) by WMX routine;
        create C(t) from P(t) by swap mutation routine;
        create C(t) from P(t) by immigration routine;
        evaluate C(t) by priGA decoding routine;
        select P(t +1) from P(t) and C(t) by
          roulette wheel selection routine;
   t ←t +1;
end
output the best solutions E
end
```

Figure 3. Procedure of priority-based genetic algorithm

the simulation is reduced, if GA parameter can be adjusted according to the situation of the group. Increasing the mutation rate, parameter of the genetic operators expands the searching space and reducing the mutation rate improves the accuracy of the local search. The searching speed and the solution accuracy can be improved by appropriately adjusting this mutation rate. Local search learning has a reputation for fast convergence and straightforward. However premature convergence makes it unsuitable for optimization problems [19]. Besides the function of priGA, hGA improves the searching ability of GA through adjusting the parameter appropriately in each generation using FLC [20] and making a suitable situation by the optimal solution search. Figure 4 shows the procedure of hGA.

4.3. **Genetic operators.** For genetic operators, the WMX (weight mapping crossover) and the exchange mutation that can avoid the local solution more easily through the combination of various crossovers and the mutations are used. The WMX crossover determines the cutting point randomly and generates the offspring exchanging the right parts of 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 selects randomly the pairs of the gene and exchanges the selected genes.

5. **Simulation.** In this section, we simulated the proposed model with the numerical examples, and the case from of a bottle distilling and sale company, in order to evaluate the model's effectiveness.

5.1. **Numerical examples.** Figure 5 shows three DCs, five retailers, ten customers, six returning centers and two processing centers one manufacturer, one disposal and one each supplier of problem 1. The data in test problems such as transportations costs, inventory costs, open costs, purchase costs, disposal costs, capacitates of manufacturer, DCs, retailers, returning centers, processing center and disposal were also randomly generated to provide realistic scenarios.

```
procedure: hGA for closed loop supply chain model
    input: data set, GA parameters (popSize, maxGen, pM, pC)
    output: the best solutions E
    begin
      t ←0;
      initialize P(t) by priGA encoding routine;
      evaluate P(t) by priGA decoding routine;
      while (not terminating condition) do
            create C(t) from P(t) by WMX routine;
            create C(t) from P(t) by swap mutation routine;
            create C(t) from P(t) by immigration routine;
            evaluate C(t) by priGA decoding routine;
    if t>u then
       auto-turning p_C, p_M and p_I by FLC;
    select P(t +1) from P(t) and C(t) by
              roulette wheel selection routine;
       t ←t +1;
      end
    output the best solutions E
    end
```

Figure 4. Procedure of hybrid genetic algorithm

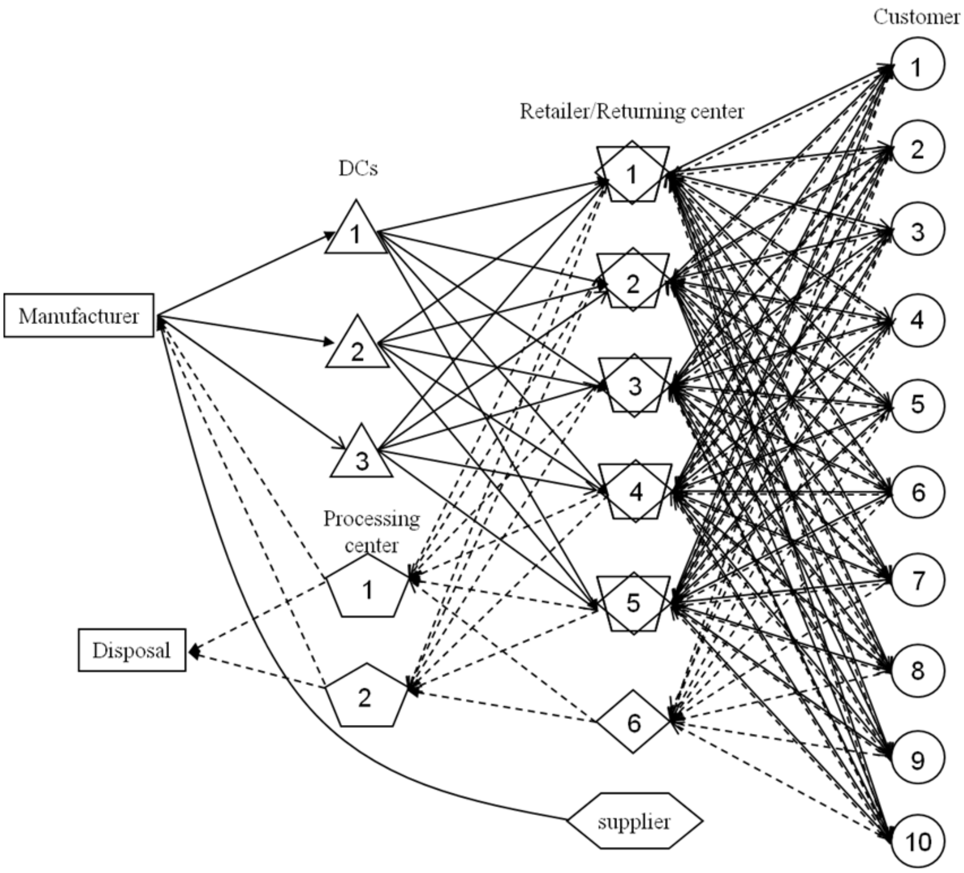

Figure 5. Example of closed loop supply chain (problem 1)

It sets to 20 of population size, 0.7 of initial WMX crossover rate, 0.3 of initial mutation rate, and 5000 of maximum generation as a simulation condition of the genetic algorithm. The crossover rate and the mutation rate have been decided by results of the exploratory experiment. However, the crossover rate and the mutation rate of each generation are adjusted because FLC is includes to hGA. To evaluate the effectiveness, the result of proposed method is compared with the solution by optimization software LINGO using 3 patterns from 355 to 18153 invariables. Table 1 shows the minimum cost and the computation time by LINGO, the minimum cost and the computation time by priGA and hGA and the relative error of cost, Gap(%) = 100 (GA solution – LINGO solution)/LINGO solution. The computation time by GA is shorter than the computation time of LINGO. However, the minimum costs of LINGO and hGA are almost the same.

The optimum cost includes the transportation cost of from manufacturer to DC, the transportation cost of from DC to retailer, the transportation cost of from retailer to customer, the transportation cost of from customer to returning center, the transportation cost of from returning center to processing center, transportation cost from processing center to manufacturer, the open cost of DC, retailer and returning center, the inventory cost of DC, retailer, returning center and processing center, purchase cost of supplier, disposal cost and saving open cost according to the retailer/returning center integration. 0.2% of the end-of life products delivered to the processing center is disposed and the disposed value is rounded off. In Figure 6, the optimal delivery routes of the example problem 2 and the results of open and integration of retailer/returning center according to forward and reverse flows are shown. In forward flow, neither retailers 3 and 15 are selected nor is open cost reduced. Moreover, in reverse flow, returning center 1, 2 and 5 was not selected, and open cost was able to be saved by integrated 11 retailer/returning centers excepting 3, 7, 10, and 15 of retailer.

5.2. **Case of bottle closed loop supply chain of distilling and sale company.** The optimization problem of closed loop supply chain case with a distilling and sale company in Busan, Korea by real data was simulated. In forward flow, the produced bottles in the plant is delivered to two kinds of DCs (shopping center and farming store), and sold through retailers (supermarket). And, in reverse flow, the empty bottles collected in the retailers are delivered to three kinds of the manufacturing plant through the recovery center of (shopping center, farming store and recycle dealer), and after processing process,

Table 1. Comparison between Lingo, priGA and hGA

Problem no.	Number of var.	Lingo		hGA		priGA		Gap (%)
		Time(s)	Cost	Time(s)	Cost	Time(s)	Cost	
1	355	2	690,030	0.20	692,880	0.28	693,420	0.41
2	7309	11	4,306,173	0.84	4,344,542	1.02	4,350,486	0.89
3	18153	90	968,876,302	5.24	987,075,864	6.82	990,322,430	1.88

Table 2. Division and numbers of items used for case study

Items / Sub-items	Retailer	DC/Returning center			plant
		Shopping center	Farming store	Recycle dealer	
No. of items	188(6233)	16	30	13	1

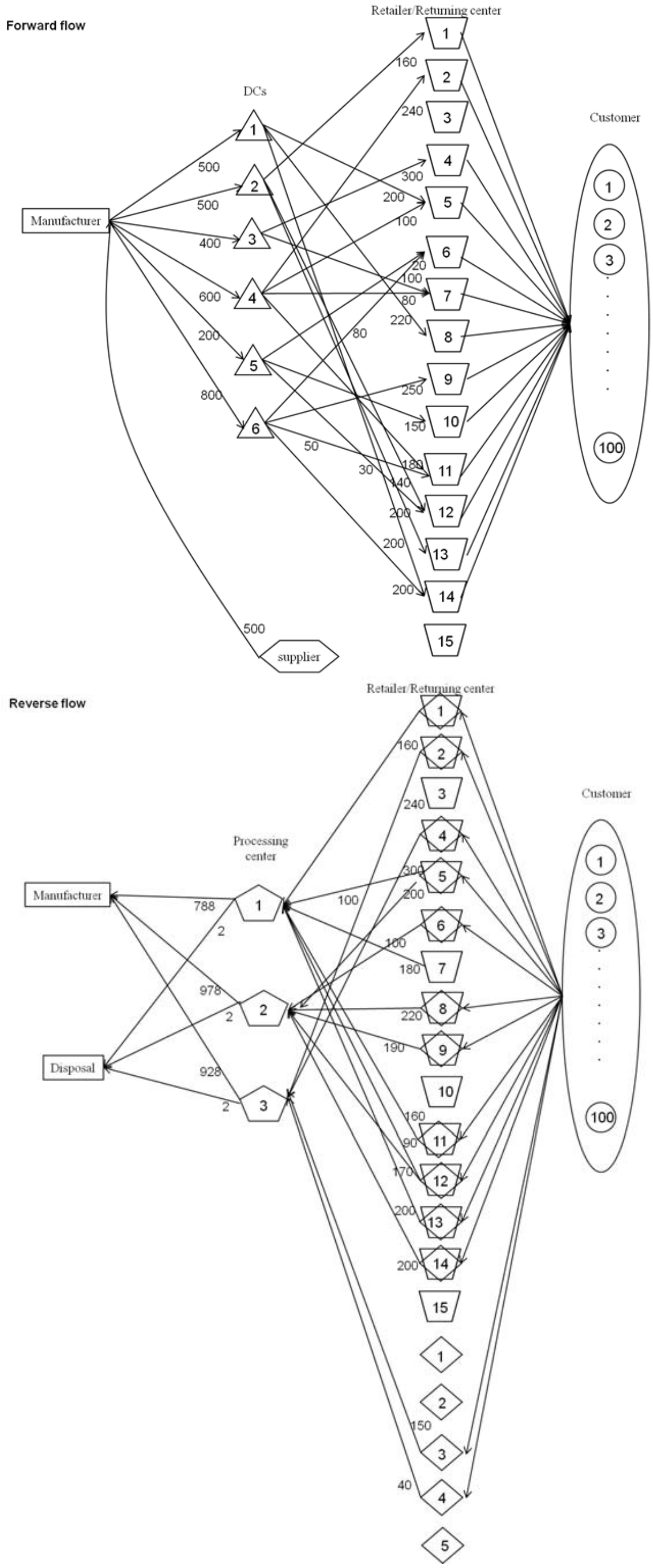

FIGURE 6. Optimal delivery routes of the example problem 2 at $t = 1$

TABLE 3. The results for cased studied

Supply chain model	Lingo	hGA	priGA
Forward flow	552,642,120	554,852,420	556,042,190
Reverse flow	518,438,600	537,648,514	546,868,702
Closed loop supply chain	968,876,302	987,075,864	990,322,430

are reused. The empty bottles to be collected are Soju bottles, and they are collected once a day. And, the recovery center is 188 minimum administrative areas in 6233 retailers (supermarket) in Busan. Moreover, each transportation cost from the retailer to the returning center is based on the fuel charge corresponding in 2008. On the other hand, it assumes the truckload quantity to be the same, 120 boxes per one truck and 30 empty bottles per one box to be loaded.

In closed loop supply chain, bottles produced from plant are transported to retailer through DC. In retailer, product and end-of-life product are treated in same time. Table 3 displays the total cost corresponding to the forward, reverse, and closed loop supply chain model using Lingo, priGA and hGA. The total cost can be reduced by integrating forward and reverse flow as shown in Table 3.

6. Conclusions.

In this study, we have proposed the integrated model with forward and reverse logistics that considered the saving of costs from integrating retailer/returning center in a multiple planning horizon. The contributions of this paper are as follows.

- The optimization method of the closed loop supply chain to minimize the transportation cost, inventory cost, open cost, purchasing cost and disposal cost is proposed.
- This paper presents calculation method of solution using optimization algorithms of the priority-based genetic algorithm (priGA) and the hybrid genetic algorithm (hGA) by Fuzzy Logic Control (FLC).
- In the experimental results comparing conventional priGA and hGA, we demonstrated the effectiveness of hGA such as shortness of computation time and better solutions.
- Through the simulation, the optimal delivery routes and the open and integration results of facilities are determined.
- Based on case study using real data for the reusable reverse logistics problem from a distilling and sale company, the effectiveness of the proposed method was improved.

Finally, we could compare of GA to other meta-heuristics such as simulated annealing, and Tabu search methods are worth investigating in future studies.

REFERENCES

[1] T. K. Eltayeb, S. Zailani and T. Ramayah, Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes, *Resources, Conservation and Recycling*, vol.55, no.5, pp.495-506, 2011.

[2] J. Lee, M. Gen, K. Rhee and H. Lee, Building of reusable reverse logistics model and its optimization considering the decision of backorder or next arrival of goods, *IEEJ Transactions on Electronics, Information and Systems*, vol.131, no.5, pp.1009-1019, 2011.

[3] P. J. Daugherty, R. G. Richey, S. E. Genchev and H. Chen, Reverse logistics: Superior performance through focused resource commitments to information technology, *Transportation Research Part E: Logistics Transport Rev.*, vol.41, no.2, pp.77-92, 2005.

[4] F. Schultmann, M. Zumkeller and O. Rentz, Modeling reverse logistic tasks within closed loop supply chains: An example from the automotive industry, *European Journal of Operational Research*, vol.171, no.3, pp.1033-1050, 2006.

[5] G. Kannan, P. Sasikumar and K. Devika, A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling, *Applied Mathematical Modeling*, vol.34, pp.655-670, 2010.

[6] H. Min, H. J. Ko and B. I. Park, A lagrangian relaxation heuristic for solving the multi-echelon, multi-commodity, closed loop supply chain network design problem, *International Journal of Logistics System*, vol.1, no.4, pp.382-404, 2005.

[7] H. Min, C. Ko and H. Ko, The spatial and temporal consolidation of returned products in a closed-loop supply chain network, *Computers and Industrial Engineering*, vol.51, pp.309-320, 2006.

[8] L. Zhao, L. Qu and M. Liu, Disruption coordination of closed-loop supply chain network (i) – Models and theorems –, *International Journal of Innovative Computing, Information and Control*, vol.4, no.11, pp.2955-2964, 2008.

[9] L. Zhao, M. Liu and L. Qu, Disruption coordination of closed-loop supply chain network (ii) – Analysis and simulations –, *International Journal of Innovative Computing, Information and Control*, vol.5, no.2, pp.511-520, 2009.

[10] J. Sheu, Y. Chou and C. Hu, An integrated logistics operational model for green-supply chain management, *Transportation Research Part E: Logistics Transport Rev.*, vol.41, no.4, pp.287-313, 2005.

[11] M. Fleischmann, P. Beullens, J. M. Bloemhof-ruwaard and L. Wassenhove, The impact of product recovery on logistics network design, *Prod. Oper. Manage.*, vol.10, pp.156-173, 2001.

[12] M. I. G. Salema, A. P. Barbosa-Povoa and A. Q. Novais, An optimization model for the design of a capacitated multi-product reverse logistics network with uncertainty, *European Journal of Operational Research*, vol.179, no.3, pp.1063-1077, 2007.

[13] H. Wang and H. Hsu, A closed-loop logistic model with a spanning-tree based genetic algorithm, *Computers & Operations Research*, vol.37, pp.376-389, 2010.

[14] B. Dengiz, F. Altiparmak and A. E. Smith, Local search genetic algorithm for optimal design of reliable networks, *IEEE Transactions on Evolutionary Computation*, vol.1, pp.179-188, 1997.

[15] M. Gen and R. Cheng, *Genetic Algorithms and Engineering Design*, Wiley, New York, 1997.

[16] H. Min, H. J. Ko and C. S. Ko, A genetic algorithm approach to developing the multi-echelon reverse logistics network for product returns, *Omega*, vol.34, no.1, pp.56-69, 2006.

[17] M. Gen, F. Altiparamk and L. Lin, A genetic algorithm for two-stage transportation problem using priority-based encoding, *OR Spectrum*, vol.28, no.3, pp.337-354, 2006.

[18] M. Gen, R. Cheng and L. Lin, *Network Models and Optimization: Multiobjective Genetic Algorithm Approach*, Springer, London, 2008.

[19] C. Vairappan, S. Gao, H. Tamura and Z. Tang, An improved learning of local search for fuzzy controller network, *International Journal of Innovative Computing, Information and Control*, vol.5, no.4, pp.1101-1113, 2009.

[20] M. Mukuda, Y. Tsujimura and M. Gen, Optimization of multiobjective system reliability design using FLC controlled GA, *IEEJ Trans. EIS*, vol.125, no.4, pp.623-630, 2005 (in Japanese).