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ALLOCATION POLICIES FOR COLLABORATIVE DELIVERY IN EXPRESS COURIER SERVICES

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Abstract. *Collaboration or strategic alliance, has recently been paid a great deal of attention as an effective way to secure competitive advantage for companies with limited resources. In the Korean express courier service market, many domestic companies of small and medium size are also interested in collaboration through sharing resources such as line-haul vehicles and service centers. The success of these collaborations depends on how the profits and operating costs are allocated to the allied companies. In this study, three allocation policies for allocating customer demand from closed service centers to newly merged service centers are proposed. A design of the express courier service network according to allocation policies is suggested considering strategic alliance. A solution heuristic based on a genetic algorithm is also suggested. Its performance is evaluated through an example problem.*
Keywords: Express courier service, Strategic alliance, Allocation policy, Genetic algorithm, Maxmin criterion

1. **Introduction.** In the express courier service industry, collaboration or strategic alliances among small and medium enterprises (SMEs) can generate economies of scale, which lead to the reduction of initial investment and operating costs. Moreover, through the efficient cooperation of service centers, participating companies may realize an increase in net profit under a win-win alliance relationship.

In this paper, three allocation policies are proposed for constructing alliance models. According to the allocation policies, we propose a conceptual alliance network design among small and medium express courier service companies. The model places participating companies in a win-win alliance relationship and suggests how to increase the net profit of each company by harnessing their low demand and under-utilized service centers and sharing consolidation terminals with available processing capacity. To verify the applicability of the model to real-world problems, we present a numerical example of the model using a data set collected from the service centers and terminals of an express courier service company in Korea. The values of parameters are generated randomly for the purpose of simulation. The study examines the feasibility of merging under-utilized courier service centers and consolidating and sharing terminals through strategic alliances between SMEs under the assumption that multiple service centers can survive in each candidate merging region.

The remainder of the paper is as follows. The previous studies related to the problem considered are introduced in Section 2. Section 3 describes definition of the problem. A solution procedure is explained in Section 4. A numerical example is performed in Section 5. The conclusions and further research areas appear in Section 6.

2. **Literature Review.** The issue of freight consolidation has been widely investigated in numerous analytical studies. In general, freight consolidation refers to a transportation option that combines a number of frequent, small shipments destined for a similar geographical region into a single large shipment in an effort to reduce shipping cost per unit and to capitalize on various freight-rate discount programs [10]. A study conducted by Cheung *et al.* [1] was the first to examine a service network design problem encountered by express couriers such as DHL Hong Kong. They proposed a hybrid optimization/simulation model that aimed to maximize service coverage and service reliability by adjusting the cutoff time. Chung *et al.* [2] also conducted another study related to the express courier service network design reflecting strategic alliance. In this study, a network design model for strategic alliances among express courier service companies through the monopoly of service centers was proposed. Moreover, it also extended their previous study by developing an integer programming model and its solution procedure based on a fuzzy set theoretic approach [3]. A nonlinear integer programming model for a strategic alliance among express companies is proposed, and a fuzzy set theoretic solution procedure is used [4]. A multi-objective programming model was also developed, maximizing the minimum expected profit increase of each participating company to examine the feasibility of merging under-utilized courier service centers and sharing consolidation terminals [5,6]. They continued the research to provide an optimization model and its solution procedure to determine the near-optimal merging scheme considering the survival of multiple service centers [7,8]. An approach to the integrated network design of collaborative courier services for the purpose of maximizing the profits of the allied partners is also developed. In this study, two collaboration issues are considered in an integration framework: an opening and (or) closing scheme of service centers and the pick-up and delivery routing of line-haul vehicles [9].

3. **Problem Statement.** In the strategic alliance model, the collaboration is operated as follows.

a) Multiple service centers can be opened, and all the other service centers within a merging region are closed after alliance.
b) The pick-up amounts of closed service centers within the same merging region are all assigned to the open service center after alliance.
c) The open service center in each merging region may reassign to their own company's consolidation terminal while satisfying the processing capacity of the terminal.
d) All terminals operated by a company are also available to other companies after alliance.

Three allocation policies for allocating the closed service centers' daily pick-up amounts are considered. The policies need to take into account the reallocating of daily pick-up amounts in the case of opening two service centers in a merging region, which is divided into three kinds of conditions.

a) The *equal allocation policy* refers to allocating equal pick-up amounts for closed service centers to open ones. Consider the case of opening two service centers in a merging region. In this case, firstly, get the sum of all closed service centers' daily pick-up amounts and then divide by two; secondly, reallocate those values to the open service center by adding the daily pick-up amounts to that service center.

$$OpenSC1 + \frac{CloseSC1 + CloseSC2}{2}$$
$$OpenSC2 + \frac{CloseSC1 + CloseSC2}{2}$$

b) The *proportional allocation policy* refers to reallocating the calculated value of the closed service centers' daily pick-up amounts to the first and second opened service centers based on the following ratio:

$$OpenSC1 + \frac{OpenSC1}{OpenSC1 + OpenSC2} * (CloseSC1 + CloseSC2)$$
$$OpenSC2 + \frac{OpenSC2}{OpenSC1 + OpenSC2} * (CloseSC1 + CloseSC2)$$

c) The *inversely proportional allocation policy* is applied as follows. If the pick-up amount for an open service center is larger than that of the other service center, then reallocate the smaller calculated value of the closed service centers' daily pick-up amounts into the first open service center. The value is calculated based on the ratio shown in this representation:

$$OpenSC1 + \frac{OpenSC2}{OpenSC1 + OpenSC2} * (CloseSC1 + CloseSC2)$$
$$OpenSC2 + \frac{OpenSC1}{OpenSC1 + OpenSC2} * (CloseSC1 + CloseSC2)$$

Consider the fair allocation policy-based alliance model. The problem is to maximize the profit of each participating company by selecting at least one service center within each merging region, which can be represented as a multi-objective non-linear integer programming model [3-9].

4. **Solution Procedure.** The solution procedure is implemented using a genetic algorithm (GA), which is a stochastic solution search procedure proven to be useful for solving combinatorial problems by adopting the concept of evolution [11]. The initial step in applying a GA is to design a suitable chromosome. This step is the key issue to the successful implementation of GA since it applies the probabilistic transition rule to each chromosome to create a population of chromosomes that represent a good candidate generation. The chromosome representation in this study is illustrated in Figure 1. The chromosome describes which service centers will be opened in each merging region where one or two service centers are allowed to be opened according to the rule in Table 1. The values of the first five genes can be selected from 1 to 10. The combination 1 through 4 shows only one service center being opened, while the others show the combinations of opening two service centers. The reallocated daily pick-up amount can be calculated according to the allocation policies. In addition, in the terminal locations, four genes represent which terminal can be allocated in each region. For example, Table 2 shows the first to the fourth genes from the terminal allocation in merging region, which means company 1's and company 4's daily pickup amounts will be reallocated to terminal 1, while company 2's and company 3's will be reallocated to terminal 2. All the values are represented by integers.

Four genetic operators are used in the proposed GA: cloning, parent selection, crossover, and mutation operators. The cloning operator copies some of the best current chromosomes in the new population; a binary tournament selection method for a parent selection

Merging Region												Non-Merging Region						
Service Center					Terminal Allocation							Terminal Allocation						
1	2	3	4	5	1	2	3	4	5	...	20	1	2	3	4	5	...	40
5	7	9	6	2	1	2	2	1	1	...	2	2	2	1	4	3	...	2
R1	R2	R3	R4	R5	R1C1	R1C2	R1C3	R1C4	R2C1		R5C4	R1C1	R1C2	R1C3	R1C4	R2C1		R10C4

FIGURE 1. Chromosome representation

Table 1. Combinations for opening and closing service centers

Combination	SC1	SC2	SC3	SC4
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	0	0	0	1
5	1	1	0	0
6	1	0	1	0
7	1	0	0	1
8	0	1	1	0
9	0	1	0	1
10	0	0	1	1

Table 2. The genes for terminal allocation in a merging region

Genes			
1	2	3	4
1	2	2	1

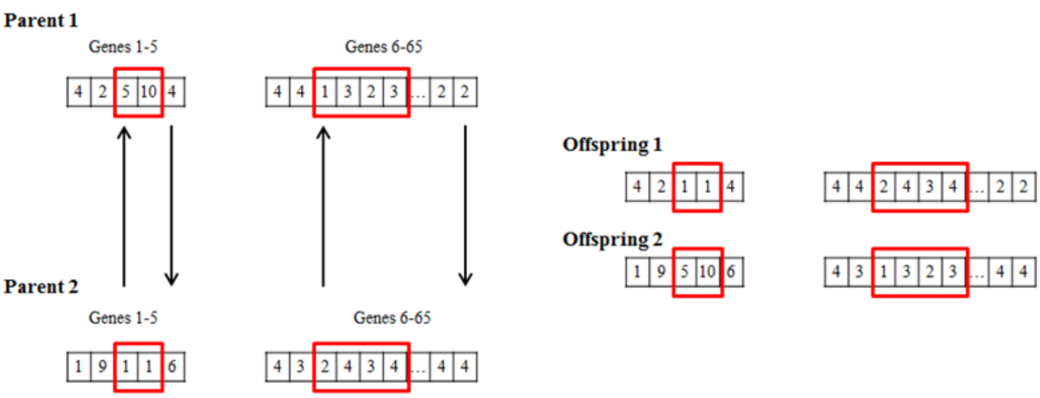

Figure 2. An example of crossover

is used, which begins by forming two teams of chromosomes. Each team consists of two chromosomes randomly drawn from the current population. The best chromosomes selected from each of the two teams are chosen for crossover operations. As such, two offsprings are generated and entered into the new population. It uses a special repairing procedure to resolve the illegitimacy caused by the two point crossover. The first point is used to assign the service center that can be opened in one region, and the second point is used to reallocate the daily pickup amount to the terminal by considering sharing the terminal.

Figure 2 shows the crossover method. The first step includes the random generation of the crossover point, which can be in any position in the parent chromosome. The offspring takes the left side of the first parent and the right side of the second parent. Then, reciprocal exchange mutation is adopted as the mutation operator. The parameter values for GA are as follows: the population size equals 200; the maximum number of generations is 150; the cloning rate is set at 2%; and the crossover rate and mutation rate are 90% and 8%, respectively.

Table 3. The result after GA implementation in a merging region

Region	Opened Service Center Location	Terminal Allocation
1	2	2
2	3	3
3	3	3
4	3	2
5	2	2

Table 4. The result after GA implementation in a non-merging region

Region	C1	C2	C3	C4
1	4	2	2	4
2	1	4	3	4
3	1	4	3	1
4	4	2	3	2
5	1	4	1	4
6	4	2	3	1
7	1	1	3	4
8	1	2	2	4
9	1	4	2	3
10	1	2	1	4

Table 5. Profits for all conditions

Company	Fair Condition	Proportional Condition	Inversely Proportional Condition
Minimum Profit	6,962.50	6,678	5,966
Total Profit	30,310	29,659	28,325

5. **Numerical Example.** A numerical example with four express courier companies is described to demonstrate the proposed approach in this study. The number of candidate merging regions is set to 10. Each company has two terminals. The terminal sets for companies 1, 2, 3, and 4 are $\{1, 2\}$, $\{3, 4\}$, $\{5, 6\}$, and $\{7, 8\}$, respectively. Every service center of the company is allocated to one terminal by generating random-numbers. The daily pick-up amount for each service center is randomly generated in the range of 10 to 50 units. The operating cost savings from closing down a service center are obtained by generating a random-number between \$50 and \$100 per day. Most of the input data regarding the current operation is also extracted from previous studies [5,7]. Tables 3 and 4 show the GA solutions using the maxmin criterion, which was developed using MATLAB7.0. In the equal condition, only a single service center is opened for each merging region; while under the proportional and inversely proportional policies, multiple service centers are opened in all merging regions. The minimum profit of the inversely proportional policy is the lowest at \$5,966 followed by the proportional policy at \$6,678, and the highest is the equal policy at \$6,962.50. The total profit represents the sum of the profits for each company and is shown in Table 5.

6. **Conclusions.** To overcome the competitiveness among express courier service companies, collaborative delivery is absolutely required. However, contrary to the necessity for collaboration, its implementation is very limited since most SMEs are not satisfied with the unfair allocation of profits and costs. Thus, this study considered three allocation policies for allocating the freight demands for closed service centers to open service centers. Also, the solution procedures for the express courier service network design were

developed according to the allocation policies. Comparisons among allocation policies are also carried out through an example problem. The application of the extended strategic alliance models according to allocation policies and continuous development for a fair allocation policy are suggested as future research areas.

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