ICIC Express Letters
Part B: Applications
Volume **7**, Number **1**, January **2016**

ICIC International ©2016 ISSN 2185-2766
pp. **197–202**

STRATEGIC PARTNERSHIP MODEL FOR PICK-UP AND DELIVERY ROUTING IN EXPRESS COURIER SERVICES BASED ON SHAPLEY VALUE ALLOCATION

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Received June 2015; accepted August 2015

Abstract. *While the express courier service market in Korea has dramatically increased, it has become more competitive, too, since many companies of small and medium size have entered the market. Strategic partnership is emerging as an issue to overcome the survival difficulties of courier companies with limited resources through sharing resources, such as vehicles and service centers. This study proposes a strategic partnership based decision making model that opens or closes service centers for pick-up and delivery routing in express courier services. Some of the service centers with low demands are serviced on a milk run from/to the consolidation terminal by line-haul vehicles, which can be represented as a traditional pick-up and delivery problem. A solution heuristic based on a genetic algorithm is also suggested for the proposed model. In particular, Shapley value is also applied for forming coalitions in express courier services with the equitable allocation to each company according to its marginal contribution. An example problem is carried out to verify the appropriateness of the strategic partnership model.*
Keywords: Express courier service, Strategic partnership, Pick-up and delivery routing, Genetic algorithm, Coalition, Shapley value

1. **Introduction.** Strategic partnership among small and medium-sized companies in express courier services has become an absolutely necessary principle for accomplishing economies of scale, which leads to the reinforcement of competitiveness through the efficient cooperation of service centers under a win-win alliance relationship. Providing better services to the customers by cooperatively utilizing their existing facilities, companies may efficiently compete to expand their market share without further investment [1-8]. Even though the benefits of strategic partnership are well known, it is very difficult to expect the success of companies since the success depends on determining how to fairly allocate profits and costs to the allied companies. In fact, most of the previous studies regarding strategic partnerships in express courier services were carried out with objective functions based on a MaxMin criterion. Chung et al. showed the total profit of the coalition based on MaxSum is larger than that based on MaxMin [1]. However, they did not propose any method for equitably allocating the profits to each allied company. The present study proposes a strategic partnership-based decision making model in which competitors share service centers for pick-up and delivery routing in express courier services. In particular, a systematic methodology is established for forming the coalition in express courier services with an equitable allocation to each company according to its contribution. The Shapley value allocation methodology [10], which is a rule for allocating common costs, is applied to estimating the contribution of each company to the coalition. The model places participating companies in a win-win alliance relationship and suggests how to increase the net profit of each company by harnessing the 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 of express courier service companies in Korea.

A study related to the express courier service network design reflecting strategic alliance was performed by Chung et al. [1]. In that study, the network design model for strategic alliances among express courier service companies through the monopoly of service centers was proposed. Moreover, they developed an integer programming model and its solution procedure based on a fuzzy set theoretic approach [2]. However, their study was performed under the assumption that only the service centers selected as candidates for strategic alliance were considered for sharing consolidation terminals. A nonlinear integer programming model for strategic alliance among express companies is proposed, and a fuzzy set theoretic solution procedure is used in this study [4]. Ferdinand et al. also developed a multi-objective programming model maximizing the minimum expected profit increase of each participating company to examine the feasibility of merging under-utilized courier service centers and sharing of consolidation terminals [5]. 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 [6-8].

The remainder of the paper is as follows. Section 2 describes the definition of the problem and a mathematical model. A solution procedure is introduced through a numerical example in Section 3. The conclusions and further research areas appear in Section 4.

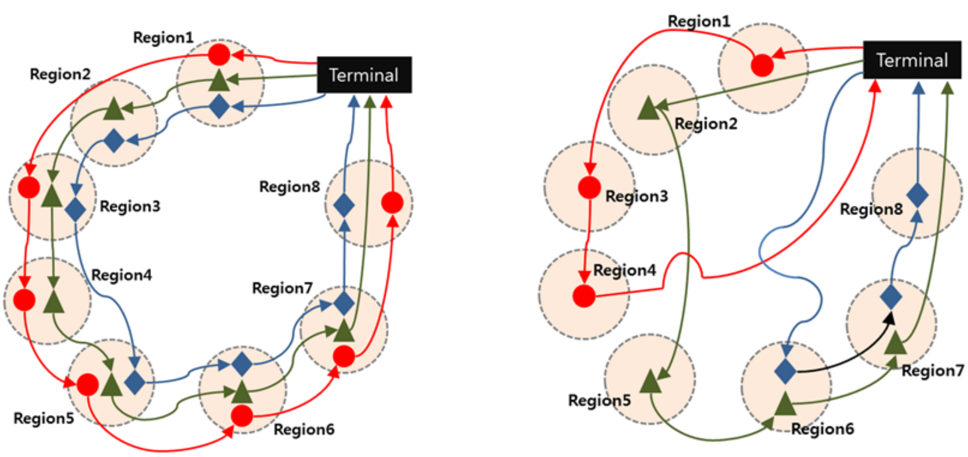
2. Problem Description.

The purpose of this study is to construct a coalition to maximize the profits of each participating company. The problem considered in this study is described in Figure 1.

There are three express delivery service companies covering eight regions, and each company has one truck for pick-up and delivery. This study is divided into two subproblems: the first is to construct a strategic partnership model with the objective of maximizing the net profit of each allied company, and the second is to determine how to fairly allocate profits to each company.

Firstly, in the strategic partnership model, the collaboration is operated as follows.

a) Multiple service centers can be opened, and all the other service centers are closed within a merging region after alliance.
b) The pick-up and delivery amounts of the closed service centers within the same merging region are all assigned to the open service center after alliance.



(a) Current operation (b) Cooperative operation after strategic partnership

FIGURE 1. Problem definition

c) Only a single vehicle for each company is operated, regardless of alliance.
d) Alliance does not affect the processing capacity of the terminal for each company.

According to Ferdinand et al. [8], the notations and mathematical formulation related to the scheme for forming a coalition are as follows:
I: Set of express delivery service companies ($i = 1, 2, \ldots, m$)
J: Set of service center regions for merging candidates ($j = 1, 2, \ldots, n$)
PO_{ij}: Profit contributed by opening for the company i's service center within region j, for $i \in I$, $j \in J$
PC_{ij}: Profit contributed by closing for the company i's service center within region j, for $i \in I$, $j \in J$
X_{ij}: Binary variable such that $X_{ij} = 1$, if the company i's service center within region j is still open, $X_{ij} = 0$ otherwise, for $i \in I$, $j \in J$

$$\begin{gathered}\text{Maximize } W_1 \\ \vdots \\ \text{Maximize } W_m\end{gathered} \tag{1}$$

subject to

$$\sum_{i=1}^{m} X_{ij} \geq 1, \quad \forall j = 1, 2, \ldots, n \tag{2}$$

$$\sum_{j=1}^{n} X_{ij} \geq 1, \quad \forall i = 1, 2, \ldots, m \tag{3}$$

where W_i denotes the incremental profit of company i given by

$$W_i = \sum_{j=1}^{n} \left\{ PO_{ij} X_{ij} + PC_{ij} \left(1 - X_{ij}\right) \right\}. \tag{4}$$

Compared to Ferdinand et al. [8], constraint (2) was changed, reflecting the first assumption a) is newly added. In this case, the pick-up and delivery amounts for closed service centers are equally allocated to open ones.

Next, a systematic methodology is established for forming a coalition in express courier services with equitable allocation to each company according to its contribution. The Shapley value allocation methodology [10] is applied to estimating the contribution of each company to the coalition. According to Tarashev et al. [11], Shapley proposed a methodology that distributes the overall value among players on the basis of their individual contributions. Adding up what individual players can achieve by themselves (the equivalent of summing up the standalone risk of each trading desk in the investment firm) is unlikely to reflect their contributions to the productivity of others. Similarly, calculating the marginal contribution of a single player as the difference between what the entire group can achieve with and without the specific individual gives only a partial picture of the individual's contribution to the work of others.

3. **Solution Procedure and Application.** A mathematical model is formulated as a nonlinear integer programming due to the first assumption, a solution procedure based on a genetic algorithm (GA) is proposed [9]. The chromosome representation in this study is illustrated in Figure 2. Since the MaxSum criterion is applied to solving the proposed model, a fitness function is defined as the sum of net profits for participating companies. Three genetic operators are used in the proposed GA: single point crossover and swap mutation are adapted. Roulette wheel selection is also applied. When there occurs an infeasible chromosome violating constraint (2) or (3), change the value of any randomly selected gene to one.

SC \ Region	R_1	R_2	R_3	……	R_n
SC_1	1	0	1	……	1
SC_2	1	1	0	……	1
⋮	⋮	⋮	⋮	……	⋮
SC_m	1	1	1	……	1

FIGURE 2. Chromosome representation (※1: Opened SC, 0: Closed SC)

TABLE 1. Routes among terminal and service centers

Company	Route
A	Yangsan T/M➡Haman➡Jinju➡Jingyo➡Hadong➡ Namhae➡Yangsan T/M
B	Yangsan T/M➡Haman➡Uiryeong➡Jinju➡Hadong➡ Namhae➡Yangsan T/M
C	Yangsan T/M➡Haman➡Uiryeong➡Jinju➡Jingyo➡ Hadong➡Namhae➡Yangsan T/M

TABLE 2. Daily pick-up and delivery amount (Unit: EA)

SC	Company A		Company B		Company C	
	Pick-up	Delivery	Pick-up	Delivery	Pick-up	Delivery
Haman	50	48	56	52	22	21
Uiryeong	–	–	28	26	17	14
Jinju	70	66	68	64	74	70
Jingyo	17	15	–	–	25	24
Hadong	27	29	15	19	17	20
Namhae	15	19	18	21	28	25
Total	179	177	185	182	183	174

TABLE 3. Daily operation cost (Unit: $)

SC	Haman	Uiryeong	Jinju	Jingyo	Hadong	Namhae
Company A	55	–	52	63	61	45
Company B	50	52	58	–	55	56
Company C	55	51	63	56	56	54

An illustrative example is provided to explain how to use the suggested solution heuristic and evaluate its performance. The data set was extracted from the three express delivery service companies in Korea. Jinju Line was introduced as a milk-run pick-up and delivery routing service; it was composed of six regions, and each company has one truck for pick-up and delivery. Tables 1 and 2 show the current routes among terminal and service centers and the average daily pick-up and delivery amounts for each company, respectively. The daily operation costs of each service center for three companies are given in Table 3.

The parameter values for the GA algorithm are as follows: the population size equals 200; the maximum number of generations is 200; crossover and mutation rates are set at 40% and 1%, respectively. Table 4 shows the solution and net profit for each company for the strategic partnership model. Figure 3 shows a screen-captured image of the implementation results for the GA.

TABLE 4. Solution for the MaxSum criterion (Unit: $)

SC	Haman	Uiryeong	Jinju	Jingyo	Hadong	Namhae	Total
Company A	0	0	1	0	0	1	712.5
Company B	1	0	0	0	0	0	527
Company C	0	1	0	1	1	0	378
Total							1,617.5

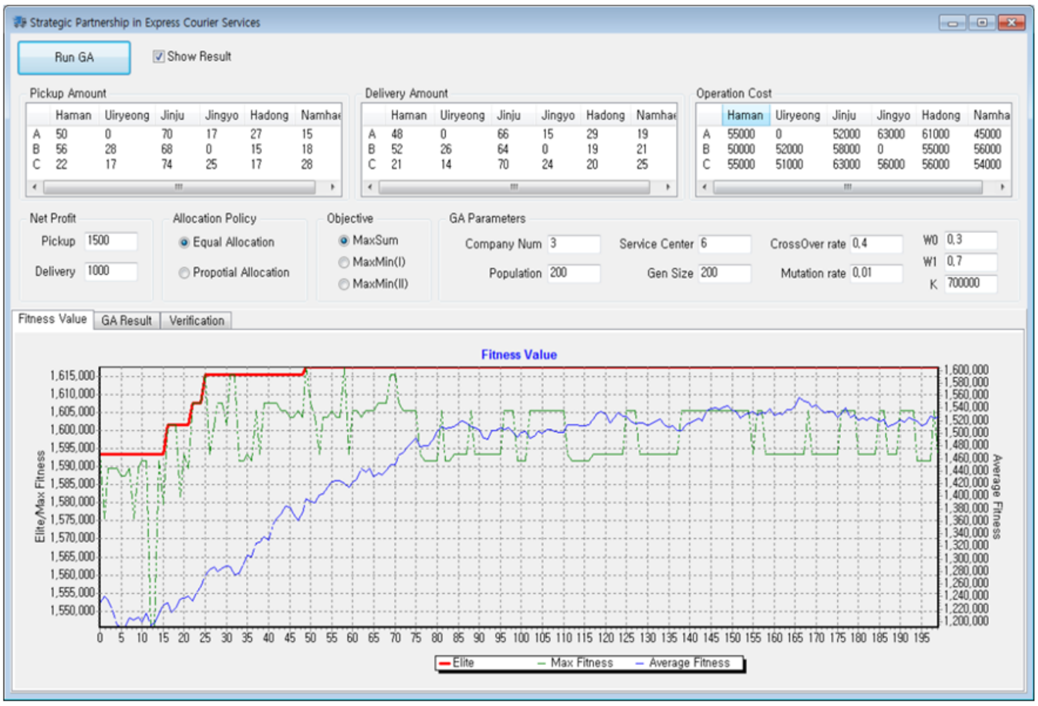


FIGURE 3. An example of the screen-captured image of the implementation results

TABLE 5. Shapley value allocation (Unit: $)

Subgroup		Subgroup output	Marginal contribution		
			A	B	C
No partnership	A	169.5	169.5		
	B	188.5		188.5	
	C	113.5			113.5
	Column Average (①)		169.5	188.5	113.5
Partnership between two companies	A, B	939	750.5	769.5	
	A, C	921.5	808		752
	B, C	926		812.5	737.5
	Column Average (②)		779.25	791	744.75
Full partnership	A, B, C (③)	1,617.5	691.5	696	678.5
	Column Sum (④ = ① + ② + ③)		1,640.25	1,675.5	1,536.75
	Shapley Value (④/3)		546.75	558.5	512.25

Finally, Table 5 shows the results for the equitable allocation to each company according to its marginal contribution by Shapley value. Compared to the results in Tables 4 and 5, a more desirable allocation is accomplished while the total profit is still sustained.

4. **Conclusions.** While the express courier service market in Korea is growing dramatically, about 80% of the market is occupied by only a few major courier services. Most express courier service companies of small and medium size suffer much difficulty due to severe competition in the market. Strategic partnership is recently emerging as a way to overcome critical survival problems. The most difficult aspect of applying a strategic partnership is determining how to allocate equitable costs and profits to the participating companies. This study considered a strategic partnership-based decision making model for pick-up and delivery routing in express courier services and suggested a genetic algorithm-based heuristic. A systematic methodology for equitable allocation to each company according to its marginal contribution was also applied. A numerical example using a real-world data set was carried out to verify the appropriateness of both the strategic partnership model and the proposed profit allocation methodology. The extension of the strategic model to the total network design in express courier services will be included in further research.

Acknowledgement. This research was supported by Basic Science Research Program though the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (NRF-2015R1D1A3A01019761).

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