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THE ECONOMICS OF SHARING IN COURIER SERVICE: NETWORK DESIGN BASED ON COALITIONAL GAME THEORY

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Abstract. *The courier service market has grown with double digits on average every year in the last decade. However, some of courier service companies in small and medium sizes are still suffering with severe competition for low prices, difficult acquisition of courier vehicles, and lack of country-wide terminals. Strategic alliance is emerging as an effective method to overcome competition pressure with limited resources. This study proposes a compromised network design model in courier service to maximize the net profit of each participating company. A co-evolutionary algorithm based heuristic is developed for solving the nonlinear programing problem. Also, a weighted Shapley value as a systematic methodology is applied for fair allocation to each company regarding the marginal contribution and investment based on the game theory.*

Keywords: Courier service, Strategic alliance, Compromised network design, Co-evolutionary algorithm, Game theory, Weighted Shapley value

1. **Introduction.** In spite of the fact that total size in Korean courier service market has been constantly increasing, the market became almost saturated because of mass market entry of companies. In particular, this situation has forced small and medium sized companies to focus their attention on efficient management of their courier service network. In this regard, strategic alliances among small and medium sized companies can be a useful idea, which can lead to the reduction of operational costs in their courier service networks by creating economies of scale. The participating companies can expect to increase net profit under a win-win situation and can provide better service to customers through joint use of their existing facilities. Through this method, they can efficiently compete to expand their market share without further investment. This study proposes a decision making model for a strategic alliance aiming to maximize the expected net profits from courier services with the consideration of the survival of multiple service centers in a merging region, the consolidation terminal sharing, and the opening/closing of consolidation terminals. The proposed model is solved using the co-evolutionary algorithm (COEA) to maximize the expected net profit of each company. Also, weighted Shapley value is applied to providing each participating company with equal coalition profit allocation regarding its marginal contribution. The remainder of the paper is as follows. In Section 2 the previous studies related to this study are introduced. The problem is precisely described in Section 3. A mathematical formulation is developed in Section 4. A

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solution procedure and model experiments are explained in Sections 5 and 6, respectively. The conclusions appear in Section 7.

2. **Literature Review.** A study with the topic of the courier service network design reflecting collaboration was first performed by Chung et al. [1]. This study proposed a network design model to form collaborations among courier service companies by monopolizing service centers. Moreover, Chung et al. [2] developed an integer programming model and its solution procedure is based on a fuzzy set theoretic approach. Chung et al. [4] also considered the survival of multiple service centers in some merging regions. They extended their previous studies with the consideration of additional assumption of sharing consolidation terminals [3]. Furthermore, another study suggested a nonlinear integer programming model for tactical cooperation among express companies and used a fuzzy set-theoretic solution procedure [5]. Ferdinand et al. [6] also developed a multi-objective programming model, maximizing the minimum expected profit of each participating company, to examine the feasibility of merging under-utilized courier service centers and sharing and closing/opening of consolidation terminals. Ferdinand et al. [7,8] continued the research to provide an optimization model and its solution procedure, which further considered that the expansion of consolidation terminal capacity affects the courier service network design. Ferdinand et al. [10] took account of collaborative pick-up and courier routing problem of line-haul vehicles as factors to maximize the incremental profits of collaborating companies. Ferdinand and Ko [9] recently proposed a coevolutionary algorithm-based approach to the collaborative network design using coalitional game theory. The contribution of this study and difference among the previous alliance models are summarized as follows: first, a mathematical model is suggested considering that only the pick-up and delivery amounts of closed service centers are equally allocated to the survived service centers in the alliance model; second, the model is developed for reflecting three modes of alliance problems such as survival of service centers and consolidation terminals, and terminal sharing simultaneously; third, a weighted Shapley value allocation is also suggested for sustaining long-term alliance.

3. **Problem Description.** This study is divided into two sub-problems: the first case is to construct a strategic alliance model with the objective of maximizing the net profit of each participating company; the second case is to determine how to allocate coalition profits to each respective company. Courier service companies generally operate a large number of service centers across the nation to collect and deliver service, most of which have sufficient volumes of shipment demand. However, some portion of them is categorized as underutilized facilities, which are unprofitably operated due to small volumes of shipment with high operating costs. In this study, the region that has low volume of daily shipment demand is called as a merging region where the underutilized service centers are valued as Type I service center. The service centers of Type I in a merging region need to be amalgamated for a strategic alliance so that the centers can earn benefit of reducing operating costs without depreciating the current service quality. On the other hand, the service centers which do not belong to any merging regions are called Type II service centers. Next, a systematic methodology is established to form a coalition in express courier services with equitable allocation to each participating company regarding its contribution. The weighted Shapley value allocation methodology is applied to estimating the contribution of each company to the alliance [13-15]. According to Tarashev et al. [16], Shapley proposed a methodology that distributes the overall value among players based on their individual contributions. One of main axioms that characterize the Shapley value is the symmetry. However, this assumption of symmetry seems unrealistic in many applications [12].

4. **Model Design.** In order to develop the mathematical formulation for this problem, some notations are introduced.

I: Set of service regions in which service centers are to be merged, $I = \{1, 2, \ldots, m\}$
J: Set of express courier companies, $J = \{1, 2, \ldots, n\}$
S_j: Set of Type II service centers of company j, $j \in J$
T_j: Set of consolidation terminals for company j, $j \in J$
T: $T = T_1 + T_2 + \cdots + T_n$
d^1_{ij}: Daily pick-up amount of company j's Type I service center in region i, $i \in I$, $j \in J$
d^2_{jl}: Daily pick-up amount of company j's Type II service center l, $j \in J$, $l \in S_j$
a_{ijk}: Indicator constant such that $a_{ijk} = 1$, if daily pick-up amount of company j's Type I service center in region i is assigned to terminal k of company j before alliance, $a_{ijk} = 0$, otherwise, $i \in I$, $j \in J$, $k \in T_j$
b_{jlk}: Indicator constant such that $b_{jlk} = 1$, if daily pick-up amount of company j's Type II service center l is assigned to terminal k of company j before alliance, $b_{jlk} = 0$, otherwise, $j \in J$, $l \in S_j$, $k \in T_j$
Q_{jk}: Capacity for terminal k of company j, $j \in J$, $k \in T_j$
r_{ij}: Net profit contributed by one unit of pick-up amount for company j's Type I service center in region i, $i \in I$, $j \in J$
w_{jk}: Net profit obtained by terminal k when one unit of pick-up amount is assigned to terminal k of company j, $j \in J$, $k \in T_j$
f_{ij}: Daily fixed cost accruing from operating company j's Type I service center in region i, $i \in I$, $j \in J$
x_{ij}: Binary variable such that $x_{ij} = 1$, if company j's Type I service center in region i is still open, $x_{ij} = 0$, otherwise, $i \in I$, $j \in J$
y_{ijpk}: Binary variable such that $y_{ijpk} = 1$, if company j's Type I service center in region i is open and the merged pick-up amount of company j's Type I service center in region i is assigned to terminal k of company p, $y_{ijpk} = 0$, otherwise, $i \in I$, $j \in J$, $p \in J$, $k \in T_p$
v_{jk}: Binary variable such that $v_{jk} = 1$, if terminal k of company j is still open, $v_{jk} = 0$, otherwise, $j \in J$, $k \in T_j$
z_{jlpk}: Binary variable such that $z_{jlpk} = 1$, if all pick-up amount of company j's Type II service center l is reassigned to terminal k of company p, $z_{jlpk} = 0$, otherwise, $j \in J$, $l \in S_j$, $p \in J$, $k \in T_p$

Thus, the problem can be described as the following multi-objective integer programming model (P) with n objective functions:
(P)

$$\begin{aligned}
\text{Max } Z_1(x) = {} & \sum_{i \in I} r_{i1} \left[\frac{\sum_{j \in J} d^1_{ij}(1 - x_{ij})}{\sum_{j \in J} x_{ij}} + d^1_{i1} - f_{i1} \right] x_{i1} \\
& + \sum_{i \in I} \sum_{j \in J} \sum_{k \in T_1} w_{1k} \left(\frac{\sum_{j \in J} d^1_{ij}(1 - x_{ij})}{\sum_{j \in J} x_{ij}} + d^1_{ij} \right) y_{ij1k} \\
& - \sum_{k \in T_1} g_{1k} v_{1k} + \sum_{j \in J} \sum_{l \in S_j} \sum_{k \in T_1} w_{1k} d^2_{jl} z_{jl1k} + C_1 \\
& \vdots \\
\text{Max } Z_n(x) = {} & \sum_{i \in I} r_{in} \left[\frac{\sum_{j \in J} d^1_{ij}(1 - x_{ij})}{\sum_{j \in J} x_{ij}} + d^1_{in} - f_{in} \right] x_{in}
\end{aligned}$$

$$+\sum_{i\in I}\sum_{j\in J}\sum_{k\in T_n} w_{nk}\left(\frac{\sum_{j\in J} d^1_{ij}(1-x_{ij})}{\sum_{j\in J} x_{ij}}+d^1_{ij}\right) y_{ijnk}$$

$$-\sum_{k\in T_n} g_{nk}v_{nk}+\sum_{j\in J}\sum_{l\in S_j}\sum_{k\in T_n} w_{nk}d^2_{jl}z_{j\ln k}+C_n \quad (1)$$

s.t.

$$1\le \sum_{j\in J} x_{ij}\le P, \quad i\in I \quad (2)$$

$$\sum_{p\in J}\sum_{k\in T_p} y_{ijpk}\le 1, \quad i\in I,\ j\in J \quad (3)$$

$$y_{ijpk}\le x_{ij}, \quad i\in I,\ j\in J,\ p\in J,\ k\in T_p \quad (4)$$

$$y_{ijpk}\le v_{pk}, \quad i\in I,\ j\in J,\ p\in J,\ k\in T_p \quad (5)$$

$$\sum_{p\in J}\sum_{k\in T_p} z_{jlpk}=1, \quad j\in J,\ l\in S_j \quad (6)$$

$$z_{jlpk}\le v_{pk}, \quad j\in J,\ l\in S_j,\ p\in J,\ k\in T_p \quad (7)$$

$$\sum_{i\in I}\sum_{j\in J}\left(\frac{\sum_{j\in J} d^1_{ij}(1-x_{ij})}{\sum_{j\in J} x_{ij}}+d^1_{ij}\right) y_{ijpk}$$

$$+\sum_{j\in J}\sum_{l\in S_j} d^2_{jl}z_{jlpk}\le Q_{pk} \quad p\in J,\ k\in T_p \quad (8)$$

$$x_{ij}\in\{0,1\}, \quad i\in I,\ j\in J \quad (9)$$

$$y_{ijpk}\in\{0,1\}, \quad i\in I,\ j\in J,\ p\in J,\ k\in T_p \quad (10)$$

$$v_{jk}\in\{0,1\}, \quad j\in J,\ k\in T_j \quad (11)$$

$$z_{jlpk}\in\{0,1\}, \quad j\in J,\ l\in S_j,\ p\in J,\ k\in T_p \quad (12)$$

5. **Solution Procedure.** A co-evolutionary algorithm (COEA) based heuristic is applied for the design of service network for strategic alliance. As the development of traditional evolutionary algorithms, the algorithm behaves in a complicated and counterintuitive way for some complex problems. Many inspirations from biology, physics, chemistry, economics, sociology, anthropology, psychology and others are adopted as its co-evolutionary mechanisms [9,11]. The procedure of COEA is described as follows.

(Step 1)

Generate the population randomly for each participating company.

(Step 2)

(a) Calculate the fitness function value of a chromosome (e.g.: Chromosome of Company A) by calculating the highest profit of all the fitness values of combined chromosomes between the chromosome (Chromosome of Company A) and all the chromosomes for the other participating companies (Chromosomes of Companies B and C).
(b) Choose a pre-specified number of chromosomes with the best fitness values to be used as the next population for each supplier. Generate/Gather the remaining number of chromosomes and add to the next population for each company.
(c) Choose the top-ten best chromosome from each supplier and save all of them into a temporary variable. Calculate the fitness function value of a chromosome by calculating the highest profit of all the fitness values of combined chromosomes between the chromosome and the best top ten chromosomes among all the chromosomes for the other suppliers.

(d) Choose the chromosome with the largest average fitness value to be the solution for each participating company.

(Step 3)

(a) Genetic algorithm (GA) is applied in each generation. A binary tournament selection method for a parent selection 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 two teams are chosen for crossover operations. As such, two off-springs are generated and entered into the new population.
(b) Crossover and mutation are applied. The first step includes 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, swap mutation is adopted as mutation operator.

There are three genetic operators used in the genetic algorithm (GA) process: crossover, mutation, and cloning. The decoded chromosome generates a candidate solution and its fitness value based on the fitness function. The purposes of GA are to generate incremental changes in the opened or closed service centers and also in the opened or closed terminals based on the set of decision variables. The co-evolutionary algorithm applies a probabilistic transition rule on each chromosome to creating a new population and representing a good candidate generation. By applying the proposed COEA based heuristic to the alliance problem, it is observed that the performance of the final solution is better compared to the traditional GA since the length of the chromosome reflecting the three modes of alliance increases too much according to the number of participating companies.

6. **Model Experiments.** There are three courier service companies for a strategic alliance in two types of regions such as merging region (Type I) and non-merging region (Type II). They are described below in more detail. 30 regions are considered, where 10 regions are merging regions and 20 regions are non-merging regions. The sets of terminals for companies 1, 2, and 3 are T1= {1, 2}, T2 = {3, 4}, and T3 = {5, 6}. Their fixed operating costs are assumed to be $1,325, $1,255, $1,474, $1,215, $1,433 and $1,328, respectively. The terminal capacity is equally assigned to 4,000 units for every terminal of three companies. Tables 1 and 2 show the current operation data for three companies, respectively. Table 1 displays the amount of daily pick-up, allocated terminal, and the daily fixed cost of Type I service center for three companies. The daily pick-up amounts

Table 1. Data for Type I service centers

Merging Region	Pick-Up Amount			Allocated Terminal			Daily Fixed Cost		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
1	40	13	13	1	3	6	82	57	62
2	50	37	17	1	3	5	58	91	59
3	35	15	42	1	4	5	64	51	95
4	37	42	23	2	4	6	87	64	72
5	34	10	26	2	3	6	71	82	62
6	27	46	17	1	4	5	81	67	69
7	29	30	21	2	4	6	58	76	76
8	28	36	43	1	3	5	82	66	82
9	18	50	50	2	3	6	85	99	81
10	19	27	42	2	4	5	99	99	79

*C1: Company 1, C2: Company 2, C3: Company 3

Table 2. Daily pickup amount for Type II service centers

Non-Merging Region	C1	C2	C3
1	483	447	159
2	478	160	277
3	384	192	410
4	354	219	278
5	107	278	156
6	382	127	389
7	114	298	416
8	257	363	289
9	357	364	203
10	201	267	254
11	432	162	221
12	193	402	396
13	124	381	410
14	436	281	463
15	279	419	175
16	186	384	499
17	500	131	197
18	244	367	315
19	374	171	309
20	428	142	310

Table 3. The COEA results

(a) The survived terminals for each company

Company	C1	C2	C3
Terminal	1	3	5

(b) Type I service centers

Merging Region	1	2	3	4	5	6	7	8	9	10
Opened Service Centers	C3	C1	C2	C2	C1	C2	C1	C1	C2	C3
Terminal Allocation	5	1	4	1	4	4	1	5	5	5

(c) Type II service centers

Non-Merging Region		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Terminal Allocation	C1	5	1	5	1	1	5	5	1	5	4	4	5	5	1	5	5	1	5	5	5
	C2	4	4	4	4	4	4	4	1	1	4	4	4	4	1	4	1	1	5	5	5
	C3	5	1	4	1	4	1	4	5	4	5	5	5	4	1	1	5	5	1	1	1

of Type II service centers are also shown in Table 2. The results by the co-evolutionary algorithm are summarized in Table 3. Based on maxsum criterion, the obtained objective function value is \$9,717 where the profits for each company are \$3,263, \$2,945 and \$3,509, respectively. Table 4 also shows the Shapley value and weighted Shapley value results by applying maxsum criterion and an allocation method by fairly allocating to each company based on its marginal contribution and investment. The marginal contribution of a company to a subgroup is calculated as the output of the subgroup minus the output of the same subgroup excluding the individual participant. Then the Shapley value of each company is the average of its marginal contributions across all differently sized subgroups. On the other hand, in weighted Shapley value allocation the weights for each participating

Table 4. Shapley value and weighted Shapley value allocations

Combination for Alliance			Marginal Contribution A	B	C
No Alliance	A, B, C ①		0	0	0
Alliance between two Companies	A+B	6,043	6,043	6,043	
	B+C	5,950		5,950	5,950
	A+C	6,300	6,300		6,300
	Average ②		6,171.5	5,996.5	6,125
Full Alliance	A+B+C ③	9,717	3,767	3,417	3,674
Shapley Value	(① + ② + ③)/3		3,312.8	3,137.8	3,266.3
Weighted Shapley Value			3,523.9	2,200.0	3,993.1

company are firstly calculated by considering total costs of survived service centers, and then are transferred to marginal contribution of each company.

7. **Conclusions.** From this study, we can conclude that a compromised model for strategic alliance among courier service companies was proposed to maximize the expected profit of each allied company by considering the survival of multiple service centers in a merging region, the consolidation terminal sharing, and the opening/closing of consolidation terminals overall. Multi-objective non-linear programming model is developed and a co-evolutionary algorithm approach is also developed. The applicability and efficiency are demonstrated through a numerical example. In addition, a weighted Shapley value as a systematic methodology was proposed for equitable allocation to each company regarding its marginal contribution and investment. Furthermore, other problems in a strategic alliance, such as extension of terminal capacity and finding a better solution procedure for strategic alliance, will be studied in future research.

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REFERENCES

[1] K. H. Chung, J. J. Rho and C. S. Ko, Strategic alliance model with regional monopoly of service centers in express courier services, *International Journal of Service and Operation Management*, vol.5, no.6, pp.774-786, 2009.
[2] K. H. Chung, C. S. Ko, Y. M. Hwang and J. J. Rho, Network design for strategic alliance in express courier services: A fuzzy set approach, *International Journal of Innovative Computing, Information and Control*, vol.6, no.1, pp.349-359, 2010.
[3] K. H. Chung, H. J. Ko and C. S. Ko, Compromised network design model for strategic alliance of service centers and consolidation terminals in express courier services, *Journal of the Korean Institute of Industrial Engineers*, vol.37, no.4, pp.304-310, 2011.
[4] K. H. Chung, H. J. Ko, F. N. Ferdinand and C. S. Ko, A fuzzy set-theoretic approach to the weak strategic alliance for the survival of multiple service centers in express courier services, *ICIC Express Letters*, vol.5, no.2, pp.385-389, 2011.
[5] F. N. Ferdinand, K. H. Chung, H. J. Ko and C. S. Ko, Genetic algorithm-based approach to multi-objective decision making model for strategic alliances in express courier services, *ICIC Express Letters*, vol.6, no.4, pp.929-934, 2012.
[6] F. N. Ferdinand, K. H. Chung, H. J. Ko and C. S. Ko, A compromised decision making model for implementing a strategic alliance in express courier services, *INFORMATION: An International Interdisciplinary Journal*, vol.15, no.12, pp.6173-6188, 2012.
[7] F. N. Ferdinand, I. Moon, K. H. Chung and C. S. Ko, A decision making model for strategic alliance-based network design in express delivery services, *ICIC Express Letters*, vol.7, no.6, pp.1813-1818, 2013.

[8] F. N. Ferdinand, K. H. Chung, E. G. Lee and C. S. Ko, Collaborative system design in express delivery services: Formulation and solution heuristic, *ICIC Express Letters, Part B: Applications*, vol.5, no.1, pp.1-8, 2014.

[9] F. N. Ferdinand and C. S. Ko, Coevolutionary algorithm based approach to the collaborative network design in express delivery services using coalitional game theory, *ICIC Express Letters*, vol.10, no.11, pp.2711-2718, 2016.

[10] F. N. Ferdinand, Y. J. Kim, H. K. Lee and C. S. Ko, A study on collaborative pick-up and delivery routing problem of line-haul vehicles in express delivery services, *International Journal of Industrial Engineering*, vol.21, no.6, pp.376-383, 2014.

[11] Z. Hu, Y. Ding and Q. Shao, Immune co-evolutionary algorithm based partition balancing optimization for tobacco distribution system, *Expert System with Applications*, vol.36, no.3, pp.5248-5255, 2009.

[12] E. Kalai and D. Samet, On weighted Shapley values, *International Journal of Game Theory*, vol.16, no.3, pp.205-222, 1987.

[13] G. Owen, A note on the Shapley value, *Management Science*, vol.14, no.11, pp.731-732, 1968.

[14] G. Owen, Multilinear extensions of games, *Management Science*, vol.18, no.5, pp.64-79, 1972.

[15] L. Shapley, A value for n-person games, *Annals of Mathematical Studies*, vol.28, pp.307-317, 1953.

[16] N. Tarashev, C. Borio and K. Tsatsaronis, The systemic importance of financial institutions, *BIS Quarterly Review*, pp.75-87, 2009.