ICIC Express Letters ICIC International ©2020 ISSN 1881-803X
Volume **14**, Number **9**, September **2020** pp. **883–890**

NETWORK DESIGN FOR COLLABORATIVE SERVICE CLUSTERING AMONG PARCEL DELIVERY COMPANIES

Ratna Permata Sari[1], Ki Ho Chung[2] and Chang Seong Ko[1,*]

[1]Department of Industrial and Management Engineering
[2]Department of Business Administration
Kyungsung University
309 Suyeong-ro, Nam-gu, Busan 48434, Korea
{ sariratna; khchung }@ks.ac.kr; *Corresponding author: csko@ks.ac.kr

Received March 2020; accepted June 2020

Abstract. *Collaboration is a reliable method for surviving in rapid market competition, particularly in the field of parcel delivery services. In general, parcel companies handle and deliver various types of items to the customers. This condition makes shipping difficult due to the fact that the shipped items are still mixed and some items require special facilities. The problem considered in this study is to specialize the delivery items of the companies to improve their competitiveness. The items are divided into certain types which consist of regular, big sized/weighted and cold items. This study aims to construct a collaboration model for maximizing the net profit of each participating company. The multi-objective programming model is proposed to describe the problem, and the maxsum criterion, maxmin criterion, and Shapley value allocation methods are applied to finding the compromised solution. The proposed approach model is shown through an illustrative numerical example.*

Keywords: Network design, Parcel delivery service, Collaborative service clustering, Shapley value allocation

1. **Introduction.** Nowadays, parcel delivery services are experiencing rapid development to fulfill the increasing demand due to customer desire for "door-to-door" delivery service in the indirect purchase market. The parcel delivery companies have developed its logistics network system with the aim of becoming faster, safer, easier to control, and easier to track in the market [1]. There are many parcel companies playing important roles in the field of delivery services. Big parcel companies focus more on speed, safety and accuracy. On the other hand, most small and medium-sized parcel companies face several problems in the rapid market competition. The recent trend for parcel delivery service market in Korea showed information that the data for parcel delivery amounts increased year by year. In contrast, the net profit decreased according to falldown in unit parcel delivery price due to tough competition in the market. The small and medium-sized parcel companies have low market share. In order to fulfill all customer needs, cooperating with other companies is necessary [2]. At this stage, the small and medium-sized companies are forced to restructure their delivery network to overcome the cost and delivery speed. They need cooperation with the other companies to survive in the global market so as not to lose their market shares. Strategic alliances are one of the strategies to achieve collective goals that directly benefit all participants. Alliances provide opportunities for all participants to share the resources, knowledge, and skills of their partners [3]. Overall, cooperation encourages joint development between companies. This allows companies to get additional benefits through sharing limited resources in terms of generating profits and this is the main goal of collaboration. Since logistics companies have benefited from economies of scale and scope, collaboration through sharing or expanding network systems

DOI: 10.24507/icicel.14.09.883

has a greater effect. In addition, sustainable collaboration is very important to upgrade the competitiveness of companies in the future. To benefit from the coalition, the initial talks between partners on the sharing of benefits derived from their cooperation are key to creating and sustaining sustainable alliances. Fair distribution of profits and allocations is also a prerequisite for ensuring long-term contracts [4]. The previous studies mentioned that the participating companies operated independently and joined the strategic alliance by sharing their facility, and they gained benefit (profit) from the collaboration [5]. The methodologies to determine optimal profit sharing allocation within sustainable collaboration were also proposed [6]. Many researchers applied various types of strategic alliances in the field of parcel delivery services [7-9].

In general, parcel delivery companies handle and deliver various types of items to the customers. This condition makes shipping difficult due to the fact that the shipped items are still mixed and some items require special pieces of equipment and facilities. Therefore, the main point considered in this study is to specialize the delivery items to improve the company competitiveness. In this study, the items are divided into certain types which consist of regular, big sized/weighted and cold items. In order to obtain a win-win strategy, this study suggests a sustainable collaboration model for a strategic alliance to increase the net profit and the competitiveness of each participating company. The proposed model also provides an alternative on how to make an efficient pick-up and delivery service system. This paper is organized as follows. This section briefly discussed the background and purpose of this research. Section 2 points the problem statement and Section 3 includes the mathematical model. Section 4 shows solution procedure in this study. The applicability of the proposed models is demonstrated through the numerical example in Section 5. Section 6 presents the conclusion and future study area.

2. **Problem Statement.** The concepts of strategic alliance and collaboration are applied as powerful survival strategies. The strategic alliance of cooperation involves the parcel service companies for sharing resources and capabilities to distribute items through efficient cooperation. The participating companies have a win-win opportunity situation due to the fact that they can provide better services to customers and can expect their realization to increase the net profit by utilizing their existing facilities.

In this study, we considered that the company in each region has to handle many items for customer order. In the case of small and medium-sized parcel companies, handling many items for each company will be costly. Thus, we are purposed to make it efficient to specialize the handling items for each company in one region. This study aims to construct a strategic alliance model with the objective of maximizing the net profit and allocating coalition profits of each participating company. The proposed collaboration model is shown in Figure 1. We also assumed that usually only a single service company can be selected for each service class in most of candidate merging regions and all the

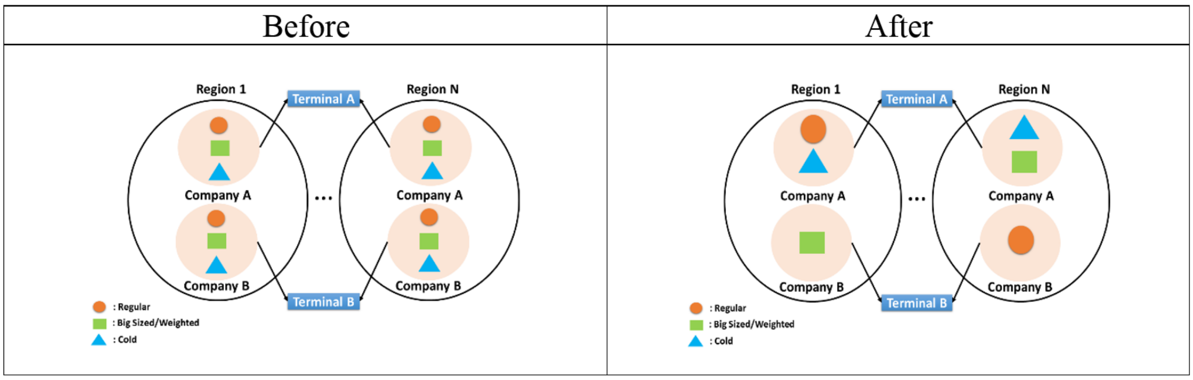

FIGURE 1. Service class-based collaboration model

other companies' service centers are stopped within a merging region after alliance. The pick-up/delivery amounts of the stopped service within the same merging region are all assigned to the selected company after alliance. The processing capacity of the terminal for each company should be satisfied for alliance.

3. **Mathematical Model.** This section provides the sets, parameters, and decision variables applied in this research. This is the mathematical model formulated as multi-objective programming and developed from the previous study [7]. The following notations are defined to formulate an optimization model for the problem:

I: set of delivery service companies, $I = \{1, 2, \ldots, m\}$
J: set of merging regions, $J = \{1, 2, \ldots, n\}$
K: set of service classes, $K = \{1, 2, \ldots, t\}$
T_i: set of terminals for the company i, $i \in I$
J_i^p: set of regions allocated to the terminal p of the company i, $p \in T_i$, $i \in I$
f_{ijk}: fixed cost accruing from operating the service class k of the company i in region j, $i \in I$, $j \in J$, $k \in K$
Q_{ip}^1: remaining capacity for processing pick-up amount of the terminal p of the company i, $p \in T_i$, $i \in I$
Q_{ip}^2: remaining capacity for processing delivery amount of the terminal p of the company i, $p \in T_i$, $i \in I$
d_{ijk}^1: daily pick-up amount with service class k of the company i within region j, $i \in I$, $j \in J$, $k \in K$
d_{ijk}^2: daily delivery amount with service class k of the company i within region j, $i \in I$, $j \in J$, $k \in K$
D_{jk}^1: daily pick-up amount with service class k within region j, $j \in J$, $k \in K$, i.e., $D_{jk}^1 = \sum_{i \in I} d_{ijk}^1$
D_{jk}^2: daily delivery amount with service class k within region j, $j \in J$, $k \in K$, i.e., $D_{jk}^2 = \sum_{i \in I} d_{ijk}^2$
w_k: weight for handling item with service class k in terminal
r_{ijk}^1: net profit contributed by one unit of pick-up amount with service class k of company i within region j, $i \in I$, $j \in J$, $k \in K$
r_{ijk}^2: net profit contributed by one unit of delivery amount with service class k of company i within region j, $i \in I$, $j \in J$, $k \in K$

Decision Variable:
x_{ijk}: binary variables such that $x_{ijk} = 1$, if the service class k of the company i in region j is selected, otherwise, $x_{ijk} = 0$, $i \in I$, $j \in J$, $k \in K$

Company i's gains or loss in net profit from being selected are

$$\sum_{j \in J} \sum_{k \in K} r_{ijk}^1 \left(D_{jk}^1 x_{ijk} - d_{ijk}^1 \right) x_{ijk} + \sum_{j \in J} \sum_{k \in K} r_{ijk}^2 \left(D_{jk}^2 x_{ijk} - d_{ijk}^2 \right) x_{ijk}$$

And, company i's fixed cost reduction from not being selected is

$$\sum_{j \in J} \sum_{k \in K} f_{ijk}(1 - x_{ijk})$$

Thus, the objective function for company i is

$$\begin{aligned} \text{Max } Z_i(x) = & \sum_{j \in J} \sum_{k \in K} r_{ijk}^1 \left(D_{jk}^1 x_{ijk} - d_{ijk}^1 \right) x_{ijk} + \sum_{j \in J} \sum_{k \in K} r_{ijk}^2 \left(D_{jk}^2 x_{ijk} - d_{ijk}^2 \right) x_{ijk} \\ & + \sum_{j \in J} \sum_{k \in K} f_{ijk}(1 - x_{ijk}) \end{aligned}$$

$$= \sum_{j\in J}\sum_{k\in K}\left(r_{ijk}^1 D_{jk}^1 + r_{ijk}^2 D_{jk}^2 - f_{ijk}\right) x_{ijk} + \sum_{j\in J}\sum_{k\in K}\left(f_{ijk} - r_{ijk}^1 d_{ijk}^1 - r_{ijk}^2 d_{ijk}^2\right)$$

The problem in this research can be explained through the following mathematical model (P) which consists of m objective functions:

$$\text{Max } Z_1(x) = \sum_{j\in J}\sum_{k\in K}\left(r_{1jk}^1 D_{jk}^1 + r_{1jk}^2 D_{jk}^2 - f_{1jk}\right) x_{1jk} + \sum_{j\in J}\sum_{k\in K}\left(f_{1jk} - r_{1jk}^1 d_{1jk}^1 - r_{1jk}^2 d_{1jk}^2\right)$$

$$\vdots$$

$$\text{Max } Z_m(x) = \sum_{j\in J}\sum_{k\in K}\left(r_{mjk}^1 D_{jk}^1 + r_{mjk}^2 D_{jk}^2 - f_{mjk}\right) x_{mjk} + \sum_{j\in J}\sum_{k\in K}\left(f_{mjk} - r_{mjk}^1 d_{mjk}^1 - r_{mjk}^2 d_{mjk}^2\right) \quad (1)$$

$$\text{s.t.} \quad \sum_{i\in I} x_{ijk} = 1, \qquad j\in J,\ k\in K \quad (2)$$

$$\sum_{j\in J_i^p}\sum_{k\in K} w_k\left(D_{jk}^1 x_{ijk} - d_{ijk}^1\right) \le Q_{ip}^1, \qquad p\in T_i,\ i\in I \quad (3)$$

$$\sum_{j\in J_i^p}\sum_{k\in K} w_k\left(D_{jk}^2 x_{ijk} - d_{ijk}^2\right) \le Q_{ip}^2, \qquad p\in T_i,\ i\in I \quad (4)$$

$$x_{ijk}\in\{0,1\}, \qquad i\in I,\ j\in J,\ k\in K \quad (5)$$

The objective function (1) represents the net profit increase of each company. Constraint (2) provides only one service center is opened in each region. Constraints (3) and (4) show the information on weight multiplication by summing the amount of pick-up and delivery amounts and by considering the processing capacity of each terminal. Constraint (5) includes decisions variables as the binary number.

4. **Solution Procedure.** The maxsum criterion, maxmin criterion, and Shapley value allocation are applied to finding the solution in this research. Maxmin criterion is one method in terms of decision-making theory with the aim of maximizing minimum profits [10]. By maxmin criterion, we can expect the profit balance of each participating company. Maxsum criterion is used to increase the total profit of each participating company within the strategic alliance. The problem in this study according to maxmin criterion can be formulated as below

$$\begin{aligned} &\text{Maximize } \alpha \\ &\text{s.t. } (2)\text{-}(5) \\ &\quad Z_1 \ge \alpha \\ &\quad Z_2 \ge \alpha \\ &\quad \vdots \\ &\quad Z_m \ge \alpha \end{aligned} \quad (6)$$

where $\alpha = \text{Min}(Z_1, Z_2, \ldots, Z_m)$.

In order to solve the problem using maxsum criterion, the problem can be written as follows:

$$\begin{aligned}&\text{Maximize } Z_1 + Z_2 + \cdots + Z_m\\&\text{s.t. } (2)\text{-}(5)\end{aligned}$$

Shapley value allocation defined a fair way of dividing the grand coalition based on the marginal contribution of each participating company. The Shapley value is called the only "fair" distribution in the context of contributions [11].

5. **Numerical Example.** The numerical example includes three parcel delivery companies (C1, C2, C3) in one merging region. Each company has a single terminal and the total number of merging regions candidate is fixed to ten. Table 1 shows the different delivery amount and daily fixed cost of the regular item, weighted item, and cold item. Total delivery amount of all items affect the terminal capacity. It is known that the daily fixed cost for weighted and cold items are higher than regular item. The high price of the weighted and cold items is due to the fact that they require special handling and equipment during the process.

Table 1. Data for delivery amount

Merging region	Delivery amount (d_{ijk})									Daily fixed cost (f_{ijk})								
	regular item			weighted item			cold item			regular item			weighted item			cold item		
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
1	87	135	111	44	68	56	29	45	37	56	92	53	155	188	171	291	271	265
2	66	51	87	33	26	44	22	17	29	86	93	76	187	185	178	272	269	254
3	138	90	120	69	45	60	46	30	40	66	81	55	182	190	170	257	254	278
4	30	78	81	15	39	41	10	26	27	63	96	76	200	178	198	253	296	278
5	144	57	126	72	29	63	48	19	42	62	94	53	167	172	162	271	278	300
6	105	126	141	53	63	71	35	42	47	80	56	63	171	155	196	300	266	250
7	87	42	111	44	21	56	29	14	37	55	57	55	157	197	165	297	255	266
8	57	69	54	29	35	27	19	23	18	95	67	68	173	170	182	264	263	280
9	60	108	57	30	54	29	20	36	19	81	93	60	169	200	167	284	268	282
10	69	150	96	35	75	48	23	50	32	72	98	75	184	172	193	291	278	286

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

The optimal solutions for the maxmin and maxsum criteria after applying the collaboration are shown in Tables 2 and 3 for each item. The main results are obtained through Excel solver. In regions 1, 4, 7 and 10, the first (C1) company's service centers are selected to be open for handling the regular items. In case of the weighted item, the first (C1) company's service centers are selected to be open in regions 1, 7 and 9. In the same regions, the second (C2) and third (C3) company's service centers are selected to be closed. On the other hand, the first (C1) company's service center is opened only in region 4 to handle the cold items. The second (C2) company's service centers are selected to be open in five regions (3, 5, 7, 9 and 10). In contrast, the first (C1) and the third (C3) company's service centers are selected to be closed within the same regions. The other service centers of all companies in any regions are closed due to the small demand for the cold items.

The values of the objective function (the profits) for companies C1, C2 and C3 are Z_1 = \$3,573, Z_2 = \$3,636, and Z_3 = \$3,605. The total profit after applying the strategic alliance is \$10,814. The optimal solution by the maxsum criterion is shown in Table 3. In regions 4, 7 and 10, the first (C1) company's service centers are selected to be open, and

Table 2. Optimal solution for the maxmin criterion

1. Regular item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j1}	1	0	0	1	0	0	1	0	0	1
x_{2j1}	0	0	0	0	0	1	0	1	0	0
x_{3j1}	0	1	1	0	1	0	0	0	1	0
2. Weighted item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j2}	1	0	0	0	0	0	1	0	1	0
x_{2j2}	0	0	0	1	0	1	0	1	0	1
x_{3j2}	0	1	1	0	1	0	0	0	0	0
3. Cold item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j3}	0	0	0	1	0	0	0	0	0	0
x_{2j3}	0	0	1	0	1	0	1	0	1	1
x_{3j3}	1	1	0	0	0	1	0	1	0	0

Table 3. Optimal solution for the maxsum criterion

1. Regular item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j1}	0	0	0	1	0	0	1	0	0	1
x_{2j1}	0	0	0	0	0	1	0	1	0	0
x_{3j1}	1	1	1	0	1	0	0	0	1	0
2. Weighted item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j2}	1	0	0	0	0	0	1	0	0	1
x_{2j2}	0	0	0	1	0	1	0	1	0	0
x_{3j2}	0	1	1	0	1	0	0	0	1	0
3. Cold item										
Region	1	2	3	4	5	6	7	8	9	10
x_{1j3}	0	0	0	1	1	0	0	0	0	0
x_{2j3}	0	0	1	0	0	0	1	1	1	1
x_{3j3}	1	1	0	0	0	1	0	0	0	0

the other companies are selected to be closed for handling the regular items. The third company (C3) opened the most service centers to handle regular items in the regions 1, 2, 3, 5 and 9. The third company (C3) also dominated in handling the weighted items. The other service centers from the first and the second companies are closed. On the other hand, the second (C2) company's service centers are opened the most for handling the cold items within all regions. The profit result is \$10,843, which is greater than the maxmin criterion. Compared with the profit results obtained from maximin criteria, the profits of companies C1 and C2 decreased becoming Z_1= \$3,067 and Z_2 = \$3,406, and the profit for company C3 increased to Z_3 = \$4,370.

The fair profit distribution according to the marginal contribution of each company is shown in Table 4 by applying Shapley value allocation. Before the alliance, all companies operate their own activities without collaboration. After the alliance among two companies, each company obtained the average profit of \$5,493, \$5,550.5, \$5,472.5 as shown in Table 4. In addition, full alliance within all companies provides a fair profit allocation of

Table 4. Shapley value allocation

Combination for alliance			Marginal contribution		
			1	2	3
No alliance	1, 2, 3 ①		0	0	0
Alliance among two companies	$1+2$	$5,571	$5,571	$5,571	
	$1+3$	$5,415	$5,415		$5,415
	$2+3$	$5,530		$5,530	$5,530
	Average②		$5,493	$5,550.5	$5,472.5
Full alliance	$1+2+3$③	$10,843	$5,313	$5,428	$5,272
Shapley value allocation	(① + ② + ③)/3		$3,602	$3,659.5	$3,581.5

Table 5. Comparison results of maxmin, maxsum and Shapley value allocation

	Maxmin		Maxsum		Shapley value	
Company 1	$3,573	33%	$3,067	28%	$3,602	33%
Company 2	$3,636	34%	$3,406	31%	$3,659.5	34%
Company 3	$3,605	33%	$4,370	40%	$3,581.5	33%
Total profit	$10,814		$10,843		$10,843	

each participating company. The companies (C1, C2, C3) obtained $3,602, $3,659.5 and $3,581.5, respectively with well balance profit range (1%).

In Table 5, we compare the profits values of each coalition companies based on maxmin, maxsum and Shapley value allocation method. Shapley value allocation emphasizes that the distribution of profit allocation is fair to each company based on its marginal contribution. However, applying the maxsum criterion improves the total benefit by coalition compared to the maxmin criterion. Therefore, it is better to apply the maxsum criterion from the perspective of the total benefit. The Shapley value allocation can solve the problem on how to share coalition profits and be a good alternative.

6. **Conclusions.** In order to survive in the rapid and competitive market, the parcel delivery companies need to increase competitiveness and sustainable collaboration through a coalition with other companies. The mathematical model for a strategic alliance among the parcel delivery companies is proposed and the solution according to maxmin and maxsum criteria is developed. The Shapley value allocation method proposed better distributing profits of each participating company. It provides a win-win strategy for increasing the net profit of all participants. Furthermore, other problems in strategic alliances, such as considering delivery service reliability, developing coordinate policy, extending the other collaboration models and applying various methodologies of coalitional game theory will be studied in the future study area.

Acknowledgment. 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-2018R1D1A3A03000944). This research was also supported by Kyungsung University research grants in 2019.

REFERENCES

[1] H. Zhu, *Logistics System and Process in Express Delivery Service Companies*, Bachelor's Thesis, Jamk University of Applied Sciences, Finland, 2010.
[2] S. Y. Ko, S. W. Cho and C. Lee, Pricing and collaboration in last mile delivery services, *Sustainability*, vol.10, 2018.
[3] E. Todeva and D. Knock, Strategic alliances and models of collaboration, *Management Decision*, vol.43, no.1, pp.1-22, 2005.

[4] M. Yea, S. Chung, T. Cheong and D. Kim, The sharing of benefits from a logistics alliance based on a hub-spoke network: A cooperative game theoretic approach, *Sustainability*, vol.10, 2018.
[5] H. Min, Consolidation terminal locatian-allocation and consolidated routing problems, *Journal of Business Logistics*, vol.17, no.2, pp.235-263, 1996.
[6] G. P. Cachon and M. A. Lariviere, Capacity choice and allocation: Strategic behavior and supply chain performance, *Management Science*, vol.45, no.8, pp.1091-1108, 1999.
[7] K. H. Chung, J. J. Rho and C. S. Ko, A strategic alliance model with regional monopoly of service centres in express courier services, *Int. J. Services and Operations Management*, vol.5, no.6, pp.774-786, 2009.
[8] 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.
[9] K. H. Chung, S. Y. Ko, C. U. Lee and C. S. Ko, Sustainable collaboration model with monopoly of service centers in express delivery services based on shapley value allocation, *The International Journal of Industrial Engineering: Theory, Applications and Practice*, vol.23, no.3, pp.166-173, 2016.
[10] G. V. Moustakides and V. S. Verykios, A MaxMin approach for hiding frequent itemsets, *Data and Knowledge Engineering*, vol.65, no.1, pp.75-89, 2008.
[11] J. Gao, X. Yang and D. Liu, Uncertain Shapley value of coalitional game with application to supply chain alliance, *Applied Soft Computing*, vol.56, pp.551-556, 2017.