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NETWORK DESIGN FOR THE TEMPORAL AND SPATIAL COLLABORATION WITH SERVICE CLASS IN DELIVERY SERVICES

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The COVID-19 pandemic has significantly impacted e-commerce and the delivery service sector. As lockdowns and social distancing measures were put in place to slow the spread of the virus, many brick-and-mortar stores were forced to close, leading to an increase in online shopping. This situation led to a surge in demand for delivery services as more people turned to the internet to purchase goods. However, this increase in demand also created several challenges for delivery companies. They experienced delays in delivering packages due to increased volume, limited staff, and disruptions to supply chains. It led to more competition and increased pressure on delivery companies to improve their services and delivery times. To overcome such competition, collaboration among small and medium-sized delivery companies can be a good way to compete with larger delivery companies. By working together, small and medium-sized companies can combine their resources and expertise to offer more extensive coverage and competitive prices than they could individually. This can help them to gain market share and expand their customer base. This study proposes a network design model for collaboration with service class in delivery services considering multi-time horizon. The problem to be considered is deciding which company is dedicated to delivering certain types of items, such as regular or refrigerated items, in designated regions in each time horizon. During the agreed-upon timeframe, the companies operate, using each other's infrastructure (such as vehicles and facilities) and sharing delivery centers for the coalition's benefit to improve efficiency and reduce costs. We also propose a multi-objective, nonlinear programming model that maximizes the incremental profit of participating companies and a linearization methodology to solve it. The max-sum criterion and Shapley value allocation methods are applied to find the best solution and ensure a fair distribution of profits among the collaborating group. The efficiency of the suggested model is shown through a numerical illustration.

Keywords: Network Design, Temporal and Spatial, Collaboration, Service Class, Delivery Service, Multi-Time Horizon, Fair Profit Distribution.

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1. INTRODUCTION

The COVID-19 outbreak has substantially affected the global economy, trade, food supply, and people's lifestyles. The demand for online shops has boomed and been on the rise since the Covid-19 pandemic, with a high emphasis on the speed and quality of the products delivered. According to the Mordor Intelligence report, more than 50.3 million people in Korea used the internet in January 2022, with more than 98% of the total population using internet services. Additionally, with an annual growth rate of 15%, South Korean consumers spend more than USD 110 billion on online consumer goods purchases yearly. Total online sales in January 2022 exceeded KRW 16.54 trillion (see Figure 1).

Moreover, parcel shipments increased significantly in 2021 in South Korea (Figure 2). 3.62 billion parcels were delivered in total, an increase of 7.59% from 2020. (3.37 billion). Additionally, from the previous year, freight volume

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increased at a rate of 9.7% in 2019, 20.9% in 2020, and 7.59% in 2021, respectively. Online meal delivery climbed by 46% in 2020, while parcel deliveries for household and health supplies, such as hand sanitizers and masks, increased by 52% yearly. Compared to 31% for books and music albums, 29% for sports and leisure items, and 16% for clothing, parcel shipment of furniture and interior goods climbed by 39%. Hanjin Transportation reported a 35% increase in operating profit for the first half, while CJ Logistics posted a 21% increase *(Source: www.mordorintelligence.com/ru/industry-reports/south-korea-domestic-courier-express-and-parcel-market)*. These delivery companies represent about 64% of the delivery market, and such large delivery companies can act quickly in a dynamic business environment by continuously optimizing their logistic systems and improving their order delivery activities. In contrast, their rival small and medium-sized companies struggle to respond on time to various changes in the market. However, small and medium size delivery companies can utilize various collaboration strategies to survive in the fierce market competition.

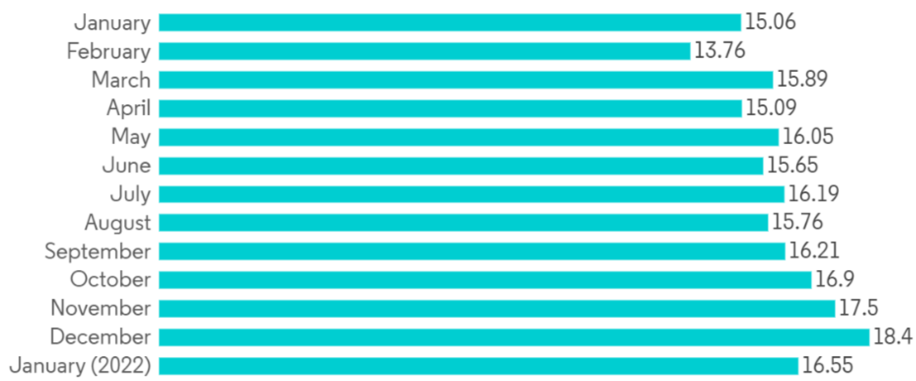

Figure 1. Revenue of E-commerce in South Korea, volume in KRW Trillion, 2021-2022 (January) Source: Statistics Korea, 2021.

They can establish mutual partnerships across the value chain to minimize service costs, improve service quality and satisfy customers. This can be achieved by aligning company strategies, consolidating available resources and service centers, streamlining material flows, and driving operational excellence. In addition, fair profit sharing from such collaboration can improve trust between partners, build strong customer relationships and boost loyalty.

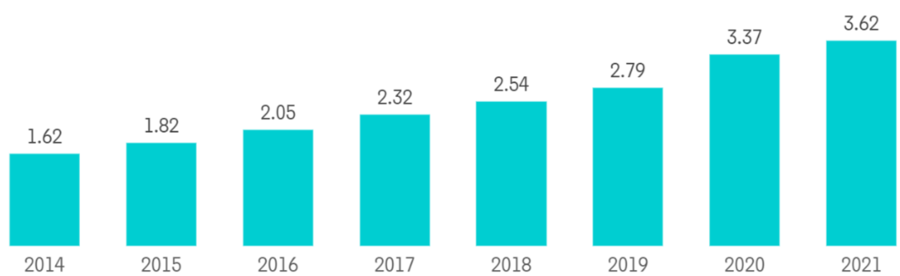

Figure 2. Volume of Parcel Shipments, Volume in Billions, South Korea, 2014-2021. Source: Korea Integrated Logistics Association (KILA), 2021.

In this paper, we propose a network design methodology for collaboration among delivery service companies in a multi-time horizon where all participants work together to increase the collaboration group's profit and obtain a fair share for its contribution. To do so, the participants shall agree to share their infrastructure for delivering different types of products (regular, refrigerated items) in target delivery regions. The primary goal of this collaboration model is to decide which company is dedicated to delivering services in the candidate regions, considering each service class (regular, refrigerated items) in each time horizon. To achieve optimal outcomes, the coalition may need to temporarily shut down operations of facilities or services that are not performing well within the collaboration system. Even though the delivery company closing the facility is not operating it, they can still benefit from each time horizon collaboration due to the improvement in overall profitability and the corresponding distribution of profits among the companies.

We also introduced a multi-objective, nonlinear programming model that maximizes the incremental profit of participating companies and a linearization methodology to solve it. In addition, the research uses cooperative game theory approaches such as Shapley value method to check the fairness and sustainability of the profit allocation.

Collaboration in delivery service can be impacted by Environmental, Social, and Governance (ESG) considerations in multiple ways. On the environmental side, companies can collaborate to develop more sustainable practices and technologies, such as using electric or hybrid vehicles, renewable energy, and sustainable packaging solutions. Collaboration can also help companies to share best practices, reduce costs, and lead to the reduction of vehicles' greenhouse gases. On the social side, companies can collaborate to ensure fair working conditions and appropriate compensation for employees. On the governance side, companies can collaborate to improve transparency, accountability and legal compliance. This can include sharing information and data on business operations, supporting regulatory initiatives, and pooling resources to address compliance and security issues.

The rest of this paper is organized as follows. Section 2 reviews the previous literature concerning the research topic. Section 3 presents the problem statement, and Section 4 builds a multi-objective mathematical model and describes some approaches to solve such a problem. Then, Section 5 provides a numerical example, which demonstrates the effectiveness of the proposed collaboration model, and lastly, Section 6 concludes with a summary of findings from the research.

2. LITERATURE REVIEW

There are many studies to improve the delivery service. Most of these studies concentrate on enhancing the competitiveness and effectiveness of independent delivery services. The primary objective is to optimize profit and costs by putting various concepts on the best use of terminals, routes, delivery and pick-up techniques, customer satisfaction implementation, and innovation. A study by Agatz *et al.* (2011) studied a fully automated approach capable of producing high-quality delivery time slot offerings quickly. Akeb *et al.* (2018) proposed a solution based on the crowd that consists of collecting and delivering parcels using individuals. To be more exact, the method uses circle packing to estimate the number of neighbors needed, the number of parcels they have to manage and the corresponding reward. Using a dynamic optimization model, Allahviranloo and Baghestani (2019) studied the transaction of pickup/delivery activities between two groups of individuals: carriers and requesters, in a P2P crowd-shipping model. The economic desirability of unmanned aerial vehicle parcel delivery and its effect on e-retailer distribution networks while considering technological limitations and customer behavior were proposed by Baloch and Gzara (2020). They consider an e-retailer offering multiple same-day delivery services, including a fast-unmanned aerial vehicle service and develop a distribution network design formulation under service-based competition. Behrend and Meisel (2018; 2019) investigated whether integrating item-sharing and crowd-shipping could facilitate collaborative consumption. Moreover, they studied an exact solution method based on a set packing formulation for which a label-setting procedure generates feasible crowd-shipper routes a priori. Min *et al.* (2006) studied a mixed-integer, nonlinear programming model and a genetic algorithm to solve the reverse logistics problem involving both spatial and temporal consolidation of returned products.

Sustainability is gaining significance in the selection of products or services by consumers (McDonach *et al.*, 2014). This is particularly true as urban traffic and pollution rise due to the e-commerce industry's growth in freight volume, and e-commerce customers are becoming more conscious of sustainability (Schöder *et al.*, 2017). As a result, e-commerce companies are trying to attract new customers and promote their values through environmental, social, and governance (ESG) activities. However, just as the competitiveness of e-commerce companies is determined in the logistics sector, their ESG activities are also carried out in conjunction with logistics.

Scholarly interest in using logistical alliances to achieve a competitive advantage in the market has lately increased. Chung *et al.* (2009) proposed a network design with a strategic alliance structure for express delivery companies. This work had several extensions (Chung *et al.*, 2016; 2018). Ghilas *et al.* (2016) incorporated an adaptive large neighborhood search heuristic algorithm to solve the pickup and delivery problem with time windows and scheduled lines. Different characteristics of delivery companies play a crucial role in differentiating their services in a time-sensitive market, which was studied by Kut (2020). Kut analyzed the interaction between the price and delivery time guarantee and its impact on the competition. Wang *et al.* (2021) proposed pickup and delivery tactics and workforce scheduling under certain or uncertain conditions. Collaboration model to maximize the net profit by considering the market density of each company and service clustering types was introduced by Ko *et al.* (2020). A collaboration model for service clustering in last-mile delivery by considering the defective rates in delivery service and introducing a penalty system to control the defect level and its effect on the profit of the collaboration group level was proposed by Makhmudov *et al.* (2021). Furthermore, Makhmudov *et al.* (2022) studied a dynamic design for a collaboration model in delivery service where companies agree to cooperate for long-term or specific periods to maximize the total profit but don't consider the types of products in the delivery collaboration.

The contribution of this study is summarized as compared to the previous studies: we consider n delivery companies who agree to form a collaboration for a number of multiple-time horizons. This collaboration aims to increase the group's profit and ensure fair distribution of profits among the participants. The plan involves sharing delivery infrastructure for various types of products and in specific regions. The methodology involves determining which company handles delivery services in candidate regions, considering the different types of products and time horizons. A multi-objective, nonlinear programming model is proposed to maximize the incremental profit of participating companies, and a linearization technique is used to solve it. Additionally, cooperative game theory methods, such as the Shapley value method, are applied to ensure fairness and sustainability of profit allocation.

3. PROBLEM STATEMENT

Considering the quick changes in the delivery service industry, the delivery companies must work together as a multi-time horizon coalition to maintain their market share and prevent falling behind existing huge companies. To achieve the primary objectives of process optimization and profit maximization, the coalition or cooperation system must develop the appropriate strategic decisions to maximize the effectiveness of the service in the serviced regions. Sometimes, the coalition may need to temporarily shut down any ineffective facilities or services within the collaboration system to get the best results. Here, the delivery company closing the facility continues to gain from the long-term collaboration due to the decision's improvement in the system's overall profitability and the associated profit split between the companies. Express delivery services typically handle and transport various goods to the final recipients. They could be typical objects, such as those of standard size and without requiring special care, or items that need refrigeration (perishable products such as milk, fish, fruits, etc.). Small and medium-sized companies are less likely to have expensive or contemporary facilities to handle these items professionally. Their capacity may vary depending on the type of product; for instance, certain companies may have modern facilities for refrigerated goods. Others, though, offer superior facilities for regular everyday products.

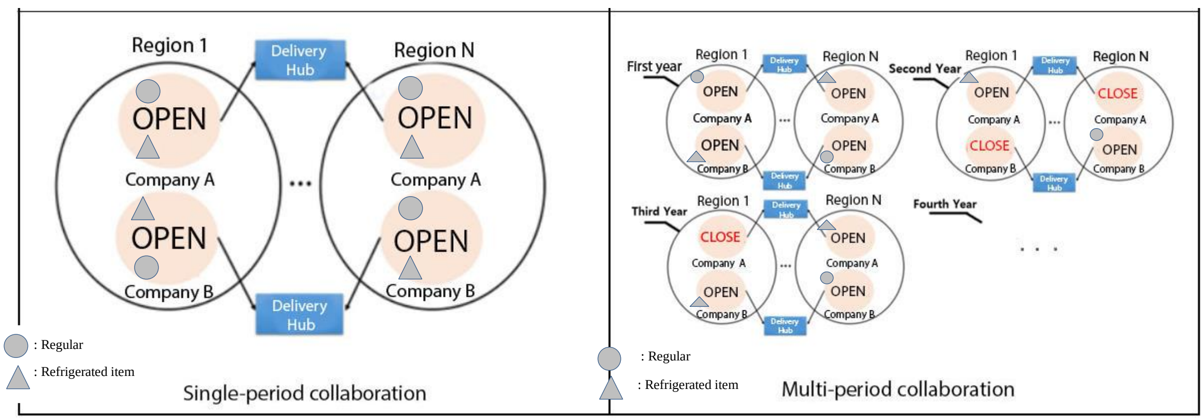

Figure 3. Comparison between single-period and multi-period collaboration

In this research, we consider delivery companies who agree to form a collaboration for some equal periods in the multi-time horizon. During the collaboration horizon, the companies agree that they will serve the pre-agreed merging regions, use common delivery hubs and facilitate the use of their infrastructure for the benefit of the coalition. There is also agreement among the companies that each has a different cost and capacity (such as a terminal's capacity) and that to get the best collaboration system results, the ineffective facilities with the highest costs or least amount of capacity may have to close down temporarily for a while (see Figure 3). A network design methodology for collaboration in a multi-time horizon model used in this study aims to identify the coalition's ideal solution in terms of (i) profit maximization and (ii) maintaining the effectiveness of the collaboration system, which necessitates decisions about whether to open or shut down a company's facilities or services.

4. MODEL DESIGN

The multi-objective integer programming methodology to optimize the expected profit gain of each participating company is described in this section. Moreover, the study constructs a multi-objective programming model based on the collaboration model introduced by Makhmudov *et al.* (2022). The study intends to extend Makhmudov *et al.*'s model to consider collaboration among delivery service companies in a multi-time horizon, to be more exact, over a number of periods and strategic decisions to open or close the facilities of the participating companies to achieve the highest efficiency. To consider the last, we construct the first non-linear problem, which is then linearized by introducing the new variables (z). The problem is solved using the max-sum criterion, where the objective function is the maximization of the profit of the overall collaboration system and the profit of each company. To construct a mathematical model, the following assumptions are considered:

a) The annual delivery demand with each service class of each company in each candidate merging region during each planning period is known.
b) Only one service center with any service class should be open in all merging regions.
c) After the alliance, the open service centers are also responsible for all the delivery amounts of other companies' service centers with any service class within the same merging region.
d) The processing capacity of the delivery hub for each company should still be satisfied after collaboration.

A mathematical model is formulated as follows:

4.1. Notation and Decision Variable

Notation:

I : set of delivery service companies, I = {$1, 2,\ldots, l$ }
J : set of merging regions, $J=\{1, 2,\ldots,m\}$
K : set of service classes, K= {$1, 2,\ldots,n$}
T : set of planning periods, $T=\{1,2,\ldots,p\}$
f_{ijkt} : fixed cost accruing from operating service region j with service class k of the company i $at\ period\ t,\ i \in I,\ j \in J, t \in T,\ k \in K$
Q_{it} : remaining capacity of the delivery hub for processing demand amount of company i $at\ period\ t, i \in I, t\in T$
d_{ijkt} : yearly demand of the company i in region j with service class k during planning period t, $i \in I,\ j \in J,\ t \in T,$ $k \in K$
D_{jkt} : yearly demand within region j with service class k during planning period t, $j \in J,\ t \in T,\ k \in K$ $i.e.,$

$$D_{jkt} = \sum_{i=1}^{m} d_{ijkt}$$

r_{ijkt} : net profit contributed by one unit of demand with service class k of company i within region j during planning period t, $i \in I, j \in J, t \in T, k \in K$
v_{ijk} : set-up cost for service region j of company i with service class k, $i\epsilon I, j\epsilon J,\ k \in K$
s_{ijk} : opportunity profit for service region j of company i with service class k, $i\epsilon I, j\epsilon J,\ k \in K$
w_k : weight for handling items with service class k in terminal

Decision variable:

x_{ijkt} : binary variables such that $x_{ijkt} = 1,$ if the service class k of company i in region j at planning period t, is selected, otherwise, $x_{ijkt} = 0,\ i \in I,\ j \in J, t \in T, k \in K$

4.2. Mathematical Model

Non-Linear Model formulation (P1):

$$Max\ \phi_1(x) = \sum_{t\in T}\sum_{j\in J}\sum_{k\in K}(r_{1jkt}D_{jkt} - f_{1jkt})x_{1jkt} + \sum_{j\in J}\sum_{t\in T}\sum_{k\in K}(f_{1jkt} - r_{1jkt}d_{1jkt}) + \sum_{t\in T-\{l\}}\sum_{j\in J}\sum_{k\in K}\{s_{1jk} \cdot x_{1jkt} \cdot (1 - x_{1jk,t+1}) - v_{1jk} \cdot (1 - x_{1jkt}) \cdot x_{1jk,t+1}\} \quad (1)$$

$$\vdots$$

$$Max\ \phi_l(x) = \sum_{t\in T}\sum_{j\in J}\sum_{k\in K}(r_{ljkt}D_{jkt} - f_{ljkt})x_{ljkt} + \sum_{j\in J}\sum_{t\in T}\sum_{k\in K}(f_{ljkt} - r_{ljkt}d_{ljkt}) + \sum_{t\in T-\{l\}}\sum_{j\in J}\sum_{k\in K}\{s_{ljk} \cdot x_{ljkt} \cdot (1 - x_{ljk,t+1}) - v_{ljk} \cdot (1 - x_{ljkt}) \cdot x_{ljk,t+1}\}$$

$s.t.$

$$\sum_{i\in I} x_{ijkt} = 1 \quad j \in J, t \in T, k \in K \quad (2)$$

$$\sum_{j\in J}\sum_{k\in K} w_k(D_{jkt}x_{ijkt} - d_{ijkt}) \le Q_{lt}\ i \in I, t \in T \quad (3)$$

$$x_{ijkt} \in \{0,\ 1\}\ i \in I, j \in J, t \in T, k \in K \quad (4)$$

The objective function (1) represents the net profit increase of each company. It includes the gain or loss of each company in profit from a change in the yearly demand amount and its reduction of fixed cost. Constraint (2) provides only one service center in which each company is opened. Constraint (3) includes the information on weight multiplication by summing the amount of demand and considering each delivery hub's processing capacity. Constraint (4) includes decision variables as the binary number.

Linear Model formulation (P2):

Binary decision variable $z_{ijkt,t+1}$is introduced to linearize the above problem as follows;

$$z_{ijkt,t+1} = x_{ijkt} + x_{ijk,t+1}$$

Decision variables can be applied in our study in the following way

$$z_{ijkt,t+1} \leq \frac{x_{ijkt} + x_{ijk,t+1}}{2}$$

The formula above provides us with the possible variants of decisions shown in Table 1.

Table 1. Matrix for possible variants for $z_{ijkt,t+1}, s_{ijtk,t+1}, -v_{ijk,t+1}$.

x_{ijkt}	$x_{ijk,t+1}$	$z_{ijtk,t+1}$	$s_{ijtk,t+1}(x_{ijkt} - z_{ijkt,t+1})$	$-v_{ijk,t+1}(x_{ijkt,t+1} - z_{ijkt,t+1})$
1	1	1	0	0
1	0	0	$s_{ijtk,t+1}$	0
0	1	0	0	$-v_{ijk,t+1}$
0	0	0	0	0

With the above variables, our model can be reformulated as follows:

$$Max\ \phi_1(x,z) = \sum_{t\in T}\sum_{j\in J}\sum_{k\in K}(r_{1jkt}D_{jkt} - f_{1jkt})x_{1jkt} + \sum_{j\in J}\sum_{t\in T}\sum_{k\in K}(f_{1jkt} - r_{1jkt}d_{1jkt}) + \sum_{t\in T-\{n\}}\sum_{j\in J}\sum_{k\in K}\{s_{1jk}(x_{1jkt} - z_{1jkt,t+1}) - v_{1jk}(x_{1jkt} - z_{1jkt,t+1})\} \tag{5}$$

$$\vdots$$

$$Max\ \phi_l(x,z) = \sum_{t\in T}\sum_{j\in J}\sum_{k\in K}(r_{ljkt}D_{jkt} - f_{ljkt})x_{ljkt} + \sum_{j\in J}\sum_{t\in T}\sum_{k\in K}(f_{ljkt} - r_{ljkt}d_{ljkt}) + \sum_{t\in T-\{n\}}\sum_{j\in J}\sum_{k\in K}\{s_{ljk}(x_{ljkt} - z_{ljkt,t+1}) - v_{ljk}(x_{ljkt} - z_{ljkt,t+1})\}$$

$s.t.$

$$\sum_{i\in I} x_{ijkt} = 1 \quad j \in J, k \in K, t \in T \tag{6}$$

$$\sum_{j\in J}\sum_{k\in K} w_k(D_{jkt}x_{ijkt} - d_{ijkt}) \leq Q_{it} \quad i \in I, t \in T \tag{7}$$

$$z_{ijkt,t+1} \leq \frac{x_{ijkt}+x_{ijk,t+1}}{2} \quad i \in I, j \in J, k \in K, t \in T \tag{8}$$

$$x_{ijkt}, z_{ijkt,t+1} \in \{0,\ 1\} \quad i \in I, j \in J, k \in K, t \in T \tag{9}$$

The objective function (5) represents the net profit increase of each company. It includes the gain or loss of each company in profit from a change in the yearly demand amount and its fixed cost reduction. Constraint (6) provides only one service center in which each company is opened. Constraint (7) involves information on the multiplication of weight by adding up the number of demands and considering the processing capacity of every delivery hub. Constraint (8) is new decision variables z, where linearize our model and responsible for opening or closing for the next period. Constraint (9) includes decision variables as the binary number.

Also, the max-sum criterion is aimed at maximizing the total profit of each participant in the collaboration model. The max-sum problem is formulated as follows (Ko *et al*. 2020; Makhmudov *et al*. 2021):

$$Maximize\ \ \phi_1 + \phi_2 + \cdots + \phi_l \tag{10}$$

$s.t.$

(6) – (9)

In addition, the Shapley value allocation (Ko *et al.*, 2020; Makhmudov *et al.*, 2021) is a solution concept from the game theory where the profits and costs of the participants in the collaboration system are shared fairly. In this paper, we assume that the collaboration is arranged so that the participants are included in the system one at a time, where each participant brings in their relevant cost and profit. It affects the total cost and profit of the whole collaboration.

5. NUMERICAL EXAMPLE

The numerical example demonstrates that the proposed collaboration model is appropriate. We assumed three parcel delivery companies (C_A, C_B, C_C). Each company has a single delivery hub, and the total number of merging regions candidates is fixed at ten. Tables 2 and 3 show the different delivery amounts and daily fixed costs for delivery of the regular and refrigerated items. The total delivery amount of all items affects the delivery hub capacity.

Table 2. Data for delivery amount.

		Regular										Refrigerated									
	Year	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
C_A	1st	95	28	41	54	82	50	85	89	75	85	59	47	31	94	98	75	67	74	64	23
	2nd	82	70	78	78	78	88	100	38	40	50	30	46	62	47	78	99	44	95	26	59
	3rd	57	90	41	35	45	49	74	91	76	36	48	51	55	40	31	27	78	72	24	87
C_B	1st	73	38	34	34	39	66	63	38	47	88	90	93	26	72	88	73	21	76	100	89
	2nd	36	79	55	80	31	70	78	72	98	22	95	81	80	49	55	46	42	57	36	81
	3rd	31	75	35	53	87	93	60	44	93	26	72	43	29	47	66	97	46	37	27	69
C_C	1st	53	76	91	43	70	71	57	66	100	35	59	87	68	97	71	83	100	20	53	58
	2nd	87	31	99	86	34	76	41	89	78	52	93	52	97	32	93	62	65	63	95	79
	3rd	24	63	68	96	83	25	98	28	91	21	43	93	48	69	98	90	84	58	68	64

* C_A: Company 1, C_B: Company 2, C_C: Company 3.

Table 2 delineates the daily fixed cost of two items in three companies. At the onset, it is clear that the daily fixed cost of refrigerated items is more high-priced than the regular item in C_A, C_B, and C_C. The reason is that refrigerated items (perishable products such as milk, fruits, vaccines, etc.) demand special appliances to deliver them safely and sound. On the other hand, the cost associated with the regular item is the lowest because there is no demand for particular equipment or storage during the delivery process. The set-up cost and opportunity profit values are assumed to be 20% and 80% of the fixed cost, respectively.

Table 3. Data for a daily fixed cost.

		Regular										Refrigerated									
	Year	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
C_A	1st	72	27	30	94	100	79	59	100	61	52	93	62	83	94	29	90	90	29	79	20
	2nd	96	28	95	36	64	99	59	63	34	49	97	53	89	61	79	98	27	96	27	89
	3rd	45	62	81	46	98	58	39	53	79	82	89	49	95	80	21	78	37	28	95	37
C_B	1st	36	58	28	51	51	42	28	85	98	86	35	73	68	23	66	61	23	22	98	61
	2nd	25	97	33	87	96	53	54	79	30	57	72	37	87	33	48	31	95	54	56	22
	3rd	40	72	24	97	94	83	41	94	86	72	67	53	35	40	88	27	41	80	42	61
C_B	1st	29	72	32	99	96	77	99	57	34	60	71	43	56	41	87	72	53	44	91	83
	2nd	23	65	37	59	35	30	60	78	58	24	64	54	63	72	99	89	58	94	69	21
	3rd	27	49	84	30	43	74	97	26	44	82	89	42	73	73	87	93	24	81	88	48

As a result of implementing the collaboration model using Excel solver, the following information is obtained, which is the optimal solution for the max-sum criterion (see Table 4):

Table 4. Optimal solution for the max-sum criterion.

		Regular										Refrigerated									
	Year	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
C_A	1st	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
	2nd	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
	3rd	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
C_B	1st	0	0	0	1	1	1	1	0	0	0	1	0	0	1	0	0	1	1	0	0
	2nd	0	0	1	0	0	0	1	0	0	0	1	0	0	1	1	1	0	1	0	0
	3rd	0	0	1	0	0	0	1	0	0	0	1	0	1	1	0	1	0	0	1	0
C_C	1st	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0	0	0
	2nd	1	0	0	0	1	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1
	3rd	1	0	0	1	1	1	0	1	1	1	0	1	0	0	0	0	1	0	0	1

The table generally shows three companies delivering two different items, such as regular and refrigerated items, to ten regions. It can be seen that C_A company is not responsible for handling either regular or refrigerated items in regions 1 and 6 in all years. In all years, Company C_B is chosen for refrigerated items to regions 1 and 4, while Company C_C is selected for regions 8, 9 and 10 to distribute regular goods three years in a row. However, 1st-year Company C_A is responsible for delivering refrigerated items to 5, 9 and 10 regions, whereas Companies C_B and C_C are not involved in handling regular items to region 2 in all years. Concerning refrigerated items, Company C_B is open for 2nd year to handling goods for regions 1, 4, 5, 6 and 8, while Company C_C is open for regions 2, 3 and 10. In conclusion, all companies' max-sum profit gained using this method is \$8,512.6, allocated as follows Z_{C_A}=\$644.60; Z_{C_B}=\$3,602.6; Z_{C_C}=\$4,265.4 as it is observed that the total profit of Company C_C is the largest one.

Table 5. Shapley value allocation.

Combination for collaboration		Output	Marginal contribution		
			C_A	C_B	C_C
No collaboration	C_A	0	0		
	C_B	0		0	
	C_C	0			0
	Column Average(①)		0	0	0
Collaboration between two companies	$C_A + C_B$	4,526	4,526	4,526	
	$C_A + C_C$	4,445	4,445		4,445
	$C_B + C_C$	4,248		4,248	4,248
	Column Average(②)		4,486	4,387	4,347
Full collaboration	$C_A + C_B + C_C$ (③)	8,513	4,265	4,068	3,987
Shapley Value			2,917	2,818	2,778

Table 5 shows the profits of each company based on the Shapley value allocation concept. The profit allocations among companies C_A, C_B and C_C are calculated as follows: \$2,917, \$2,818, and \$2,778, respectively. Results show that company C_A receives the highest allocation in profit (\$2,917). Total profit is equal to \$8,513

6. CONCLUSIONS

ESG (Environmental, Social, and Governance) trends can impact temporal collaboration with service classes in delivery services in many ways. For example, if a delivery company strongly focuses on environmental sustainability, it may prioritize using electric vehicles or implementing more efficient routing systems to reduce emissions. This could potentially lead to a reduction in the number of delivery vehicles on the road, which could impact the schedule and availability of drivers. Companies that prioritize social issues may also implement policies that ensure fair working conditions for delivery drivers and couriers, such as providing benefits or setting strict safety standards. This could impact the company's labor costs, which could, in turn, affect the budget for hiring and training service class employees.

Moreover, governance is also an important aspect of any company. Companies with strong governance standards may choose to set strict standards for the service class, which could impact the training required to provide the desired level of service. And also provide employee benefits for long-term retention.

Collaborative delivery considered in this study is one of the strategies directly connected to all three elements of ESG, environment, social, and governance. We proposed an approach for service network design in collaborative delivery services in a multi-time horizon to maximize allied delivery companies' incremental profit. A multi-objective, nonlinear programming model was developed and solved by a linearization methodology. A procedure for fair distribution of profits was also introduced for the sustainability of collaboration.

As further research areas, we can add several delivery operation characteristics to the considered collaborative such as delivery service quality, volatility of delivery service demand and inventory of fulfillment center, etc. The limitation of our model in terms of validation is beyond the scope of this study, and it is a remaining task to validate our model in the future.

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REFERENCES

Agatz, N., Campbell, A., Fleischmann, M., and Savelsbergh, M. (2011). Time Slot Management in Attended Home Delivery. *Transportation Science*, 45(3): 435–449.

Akeb, H., Moncef, B., and Durand, B. (2018). Building a Collaborative Solution in Dense Urban City Settings to Enhance Parcel Delivery: An Effective Crowd Model in Paris. *Transportation Research Part E: Logistics and Transportation Review*, 119: 223–233.

Allahviranloo, M., Baghestani, A. (2019). A Dynamic Crowdshipping Model and Daily Travel Behavior. *Transportation Research Part E: Logistics and Transportation Review*, 128: 175–190.

Baloch, G., and Gzara, F. (2020). Strategic Network Design for Parcel Delivery with Drones Under Competition. *Transportation Science*, 54(1): 204–228.

Behrend, M., Meisel, F. (2018). The Integration of Item-Sharing and Crowdshipping: Can Collaborative Consumption be Pushed by Delivering Through the Crowd?. *Transportation Research Part B: Methodological*, 111: 227–243.

Behrend, M., Meisel, F., Fagerholt, K., and Andersson, H. (2019). An exact solution method for the capacitated item-sharing and crowdshipping problem. *European Journal of Operational Research*, 279(2): 589–604.

Chung, K. H., Ko, S. Y., and Ko, C. S. (2018). A Cooperative Game Theoretic Network Design for Collaborative Operation of Service Centers and Consolidation Terminals in Delivery Services. *The International Journal of Industrial Engineering: Theory, Applications and Practice*, 25(1): 18-28.

Chung, K. H., Ko, S. Y., and Lee, C. U. (2016). 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*, 23(3): 166-173.

Chung, K. H., Rho, J. J., and Ko, C. S. (2009). A Strategic Alliance Model with Regional Monopoly of Service Centres in Express Courier Services. *International Journal Services and Operations Management*, 5(6): 774-786.

Ghilas, V. Demir, E. Van Woensel, T. (2016). An Adaptive Large Neighborhood Search Heuristic for the Pickup and Delivery Problem with Time Windows and Scheduled Lines. *Computers & Operations Research*, 72: 12–30.

Ko, S. Y., Sari, R. P., Makhmudov, M., and Ko, C. S. (2020). Collaboration Model for Service Clustering in Last-Mile Delivery. *Sustainability*, 12(14): 5844.

Kut, C. S. (2000). Price and Time Competition for Service Delivery. *Manufacturing & Service Operations Management*, 2(4): 392-409.

Makhmudov, M., Lee, G. M. and Ko, C. S. (2021). Fair Profit Distribution in Delivery Service Collaboration Considering Service Quality. *The International Journal of Industrial Engineering: Theory, Applications and Practice*, 28(2): 228-238.

McDonach, P., Prothero, A. (2014). Sustainability marketing research: Past, present and future. *Journal of Marketing Management*, 30(11-12): 1186–1219.

Makhmudov, M., Chung, K.H., Friska, N., and Ko, C. S. (2022). Dynamic Design for Collaborative Delivery Services. *ICIC Express Letters*,16(11),

Min, H., Ko, C. S. and Ko, H. J. (2006). The Spatial and Temporal Consolidation of Returned Products in a Closed-Loop Supply Chain Network. *Computers and Industrial Engineering*, 51(2): 309-320.

Schöder, D., Ding, F. and Campos, J. (2016). The impact of e-commerce development on urban logistics sustainability. *Open Journal of Social Sciences*, 4(3): 1-6.

Wang, C.N., Nhieu, N.L., Chung, Y.C. and Pham, H.T. (2021). Multi-Objective Optimization Models for Sustainable Perishable Intermodal Multi-Product Networks with Delivery Time Window, *Mathematics*, 9: 379.