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ALLOCATION OF LOGISTICS SHARING COST IN REFRIGERATED LOGISTICS WAREHOUSE

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Abstract. *In Korea, it is difficult for low-temperature warehouse companies to operate due to increased storage space and reduced production, and individual wanted transportation costs are increasing. To solve this problem, this study suggested a way to collaborate with each other by applying a shared logistics system to each cold storage company. The purpose of this study is to efficiently allocate shared profits to each cold storage company through the Shapley Value method by applying commodity quantity, commodity demand, transportation cost and fixed cost to the logistics sharing system. Through this, the goal is to reduce competition among low-temperature warehouse companies and to cooperate with each other through the application of a shared logistics system.*
Keywords: Cold chain, Shapley Value, Logisitcs sharing, Cooperative game theory, Minsum, Minmax

1. **Introduction.** Korea is having difficulty in sending a wanted warehouse due to the increase in storage capacity and the failure to fill the entire transportation volume in the operation according to the route [1]. In addition, difficulties in production and operation have resulted in rate dumping, which has disadvantaged many companies. Therefore, the importance of public goods is emphasized. To solve these problems, this study applied a shared logistics system to the wanted delivery system of cold storage companies. If each cold storage company uses its affiliate's vehicles through a shared logistics system, it will reduce the cost of sending wanted goods and increase efficiency. In this study, the sharing profit obtained by applying the logistics sharing system to the wanted delivery system of low-temperature warehouse companies is calculated as Minmax and Minsum, and the sharing profit is efficiently distributed to companies by Shapley Value [2]. Ferdinand et al. studied that resources and profits are generated through sharing and that clear distribution of profits is needed for win-win and operation among businesses [3]. In the case

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of Ferdinand et al., the sharing was grafted onto the container storage space in the terminal and the mixed supply chain was studied [4]. This study deals with the application of a logistics sharing system in which a certain space in a vehicle is interchanged and wanted. The logistics industry without exception is aware of the importance of sustainable development. To achieve this goal, the logistics industry is leveraging cutting-edge technologies, such as product service systems (PSS) and cloud manufacturing (CMfg), to design logistics product service systems (LPSS) [5]. Furthermore, using the mathematical model of this paper, we were able to reduce the operating costs of companies and mitigate competition. The introduction of Chapter 1 shows the overall background and research status. Chapter 2 describes the refrigerated logistics warehouse sharing logistics system of this study. Chapter 3 describes the mathematical model of the refrigerated logistics warehouse sharing logistics system. Chapter 4 shows a real example of a refrigerated logistics warehouse sharing logistics system. Chapter 5 concludes the contents of this study.

2. **Refrigerated Logistics Warehouse Sharing Logistics System.** Shared logistics system refers to the creation of economic benefits by sharing resources or service capabilities with individuals or logistics companies that have sufficient resources or service capabilities [4-6]. Figure 1 shows an example of a shared logistics system. Although the existing wanted delivery system was sent by each cold storage company without filling the amount of transportation, the shared logistics system can not only increase vehicle efficiency but also reduce the cost of wanted delivery by 12 percent, unlike the existing wanted delivery system.

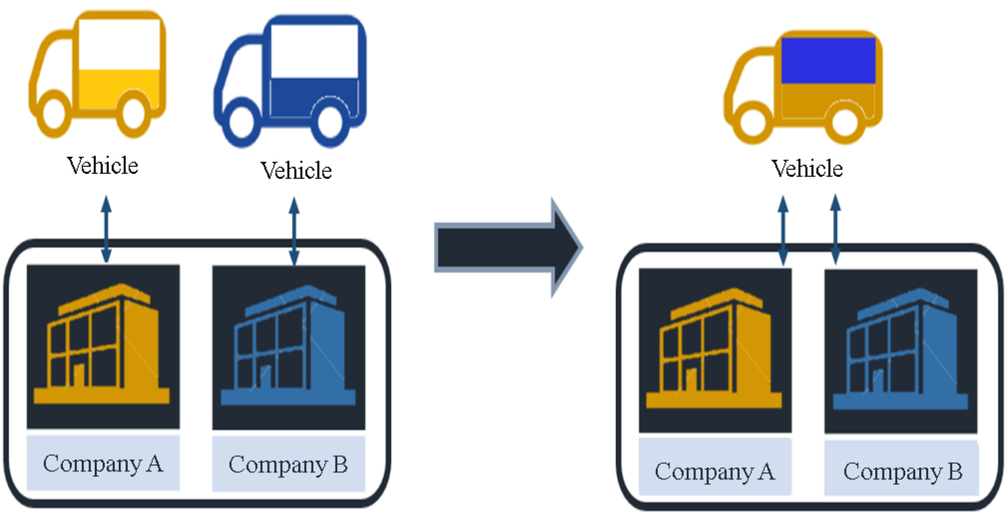

Figure 1. Operation of refrigerated logistics warehouse sharing logistics system

3. **Analysis of Refrigerated Logistics Warehouse Sharing Logistics System.** In order to establish a shared refrigerated logistics warehouse logistics system, the assumptions of this study are as follows. First, a shared logistics system can be applied to cold storage companies that transport the same route, and a wanted shipment can be made by exchanging certain spaces on the vehicle [7-10]. Second, the number of cold storage companies applying the shared logistics system is two or more, and the route of the vehicle's wanted transmission is known [11]. Third, the quantity of wanted goods is determined by each route. Fourth, the fixed and variable costs of the vehicle occur. Based on these assumptions, the symbols and variables required to create a mathematical model are defined as follows.

W: Set of refrigerated logistics warehouse

H_i: Collection of vehicles in possession of refrigerated logistics warehouse, $i \in W$

R: Set of routes for which goods must be transported

U_{ihr}: Quantity values for storing allied goods on vehicle h of refrigerated logistics warehouse i carrying paths r, $i \in W$, $h \in H_i$, $r \in R$

T_{ihr}: Fixed ratio of vehicle h in refrigerated logistics warehouse i carrying path r, $i \in W$, $h \in H_i$, $r \in R$

D_{ir}: Demand for goods to be transported by refrigerated logistics warehouse i on route r during the planned period, $i \in W$, $r \in R$

C_{rih}: Transportation fee for vehicle h of refrigerated logistics warehouse i to transport r route once, $i \in W$, $h \in H_i$, $r \in R$

E_{rijh}: For items of refrigerated logistics warehouse i loaded on vehicle h of refrigerated logistics warehouse j carrying route r transportation cost per item paid by refrigerated logistics warehouse i to refrigerated logistics warehouse, $i, j \in W$, $i \neq j$, $h \in H_i$, $r \in R$

N_{rijh}: On vehicle h of refrigerated logistics warehouse j carrying r, off duty cost, $i, j \in W$, $i \neq j$, $h \in H_i$, $r \in R$

F_{rjh}: Fixed cost of vehicle h in refrigerated logistics warehouse j carrying long, $i, j \in W$, $i \neq j$, $h \in H_i$, $r \in R$

M_{ihr}: Maximum number of times vehicle h in cold storage i can transport the route r, $i \in W$, $h \in H_i$

Q_{jh}: Quantity of goods that can be loaded on vehicle h of refrigerated logistics warehouse i, $i \in W$, $h \in H_i$

y_{rijh}: Goods in refrigerated logistics warehouse i that are transported by vehicle h of refrigerated logistics warehouse j that transports the r route quantity, $i, j \in W$, $i \neq j$, $h \in H_i$, $r \in R$

z_{rijh}: The number of times that refrigerated logistics warehouse i uses vehicle h of refrigerated logistics warehouse j to transport the route r, $i, j \in W$, $i \neq j$, $h \in H_i$, $r \in R$

$$Min\ Z_m = \sum_{h \in H_i} \sum_{r \in R} C_{r^m h} x_{r^m h} + \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} \sum_{r \in R} N_{r^m h} z_{r^m h} + \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} \sum_{r \in R} E_{r^m h} y_{r^m h}$$

$$Min\ Z_m = \sum_{h \in H_i} \sum_{r \in R} C_{r^1 h} x_{r^1 h} + \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} \sum_{r \in R} N_{r^1 h} z_{r^1 h} + \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} \sum_{r \in R} E_{r^1 h} y_{r^1 h}$$

$$\text{s.t. } x_{rih} \leq \sum_{r \in R} M_{rih}, \quad i \in W,\ h \in H_i \tag{1}$$

$$y_{rijh} \leq \sum_{r \in R} M_{rih}, \quad i \in W,\ h \in H_i,\ r \in R \tag{2}$$

$$\sum_{h \in H_i} Q_{ih} x_{rih} - \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} y_{rijh} + \sum_{\substack{j \in W \\ j \neq i}} \sum_{h \in H_i} y_{rjih} \leq D_{ir}, \quad i \in W,\ r \in R \tag{3}$$

$$\sum_{\substack{j \in W \\ j \neq i}} y_{rijh} \leq U_{ihr} x_{rih}, \quad i \in W,\ h \in H_i,\ r \in R \tag{4}$$

$$z_{rijh} \leq x_{rih}, \quad i, j \in W,\ i \neq j,\ h \in H_i,\ r \in R \tag{5}$$

$$x_{rih} \geq 0,\ x_{rih}\text{: integer} \quad i \in W,\ h \in H_i,\ r \in R \tag{6}$$

$$y_{rijh} \geq 0,\ y_{rijh}\text{: integer} \quad i, j \in W,\ i \neq j,\ h \in H_i,\ r \in R \tag{7}$$

$$z_{rijh} \geq 0,\ z_{rijh}\text{: integer} \quad i, j \in W,\ i \neq j,\ h \in H_i,\ r \in R \tag{8}$$

Constraint (1) prohibits vehicles of each cold storage enterprise from being transported in excess of the number of times each route is transported. Constraint (2) means that the transport demand for each route must be transported. Constraint (3) means a constraint on other cold storage items that can be transported according to individual vehicles. The pharmaceutical formula (4) shall not exceed the number of times that each cold storage company uses a vehicle from a cold storage company that transports its route. A pharmaceutical formula (5) indicates that the goods cannot be loaded unless the cold storage entity uses a vehicle carrying the route. Pharmaceuticals (6)-(8) indicate non-negative and hydrostatic constraints.

4. Sharing a Refrigerated Logistics Warehouse Logistics System Analysis.

4.1. **Case study.** This study cited examples of three cold storage companies forming partnerships, assuming that there are four routes to be transported and ten, eight and eight vehicles each. The period is set to one month. Table 1 represents the operating costs of vehicles by company and Table 2 represents the cost of shared transportation by company and the cost of getting loading and unloading. The number of transports on each table is the number of vehicles operating during the planned period of the month. For example, Company A operated route 1, 2, 3 with 10 vehicles for a month.

Table 1. Operating costs of vehicles by company

Company	Kind of vehicle (Unit: Ton)	Number of vehicles	Number of transports (Transportation cost, Unit: $10)			Fixed cost (Unit: $10)
			1	2	3	
A	5	3	22(276)	22(276)	23(312)	3,772
	2.5	5	43(156)	23(168)	43(204)	2,980
	1	2	10(126)	6(132)	7(168)	2,450
B	2.5	3	22(150)	22(166)	23(210)	3,040
	1	5	23(127)	43(133)	43(174)	2,499
C	2.5	4	43(154)	22(167)	24(206)	3,010
	1	4	22(126)	43(132)	24(172)	2,475

Table 2. Shared transportation costs, loading and unloading costs by company

Company	Kind of vehicle (Unit: Ton)	Shared transportation cost (Unit: $10/Kg)			Vehicle on and off, cost (Unit: $10/Kg)		
		1	2	3	1	2	3
A	5	0.8	0.5	0.7	10	11	12
	2.5	0.9	0.6	0.8	9	10	10
	1	1.0	0.7	0.9	10	11	10
B	2.5	1.3	0.3	0.7	10	10	9
	1	1.5	0.4	0.8	10	9	11
C	2.5	1.1	0.6	0.6	11	9	9
	1	1.2	0.7	0.9	10	11	12

4.2. **Cost allocation of shared logistics systems.** In this study, the costs of individual transport and Minmax and Minsum for allocating the costs of shared logistics systems are summarized as shown in Table 3.

Table 3 may calculate the marginal contribution of an individual entity to two or three allied groups. Table 4 indicates the calculation of the value of the Shapley to obtain the marginal contribution of the enterprise by partnership.

The cost savings resulting from the partnership between the three companies are $12,992 (108,270 − 95,278) and, depending on the value of the Shapley Value, Entity A is $4,792 and Entity B is $4,292 and Entity C is $3,909. Therefore, using the mathematical model

Table 3. No collaboration and Minmax, Minsum cost

(Unit: 10$)

Sortation	Company	Cost			Total
		A	B	C	
No collaboration		45,310	35,310	27,650	108,270
Minmax		32,481	32,481	32,481	97,443
Minsum between two companies	A, B	35,959	36,599	0	72,558
	A, C	34,832	0	30,832	65,664
	B, C	0	25,332	27,650	56,664
Minsum full collaboration	A, B, C	30,759	37,759	26,759	95,278

Table 4. Marginal contributions by inter-company partnerships

(Unit: 10$)

Sortation	Company	Subgroup output	Marginal contribution		
			A	B	C
No collaboration	A, B, C	0	0	0	0
Collaboration between two companies	A, B	8,062	8,062	8,062	0
	A, C	7,296	7,296	0	7,296
	B, C	6,296	0	6,296	6,296
	AVG.		7,679	7,179	6,796
Full collaboration	A, B, C	12,992	6,696	5,696	4,930
Column Sum			14,375	12,875	11,726
Shapley Value			4,792	4,292	3,909

of this paper, we were able to represent an increase in operating costs and a competitive easing for each company.

5. **Conclusion.** This study is a study in which two or more cold storage companies form partnerships and determine the cost, transport status, and number of times of transport of vehicles by route to minimize costs when applying a shared logistics system. The mathematical model is a multi-purpose decision model consisting of multiple purpose functions, each of which has participated in the partnership. Although conservative approaches by the Minmax criterion are often used a lot, this study also applied the Minsum criterion and compared it. By applying Minsum and Minmax, the total cost of partnership was reduced compared to when cold storage companies operate on their own without partnership. Applying the Minmax criterion results in generally equal costs, but overall costs are higher than applying the Minsum criterion. Thus, it could be seen that the cost savings would be greater when applying the Minsum criterion compared to the Minmax criterion. However, since Minsum will result in uneven distribution of cost-saving effects, this study suggested a method of rationally allocating shared costs using Shapley Value. The operation through the shared logistics system presented in this study will enhance the collaboration and competitiveness of the companies participating in the partnership, and it is believed that it can be used as a basis for research for business cooperation. This study will help develop and apply the collaborative system and cooperate in national policy and the mathematical model of this paper will mitigate future inter-company competition and rate dumping phenomena. It will also be cited in various reports as part of national, logistics policy.

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