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Allocation of Logistics Sharing Cost in Refrigerated Logistics Warehouse

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Introduction & Research Questions

1) S. 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. Therefore, the importance of public goods is emphasized.

2) This study applied a shared logistics system to the wanted delivery system of cold storage companies.

3) 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 Min-max and Min-sum, and the sharing profit is efficiently distributed to companies by Shapley value.

Mathematical Formulas

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

$$\boldsymbol{Min\ Z_1} = \sum_{h\in H_i}\sum_{r\in R} C_{r}^{1}{}_{h}\, x_{r}^{1}{}_{h} + \sum_{\substack{j\in W\\ j\neq i}}\sum_{h\in H_i}\sum_{r\in R} N_{r}^{1}{}_{h} z_{r}^{1}{}_{h} + \sum_{\substack{j\in W\\ j\neq i}}\sum_{h\in H_i}\sum_{r\in R} E_{r}^{1}{}_{h}\, y_{r}^{1}{}_{h}$$

S.t

$$\sum_{r\in R}\frac{1}{M_{rih}} x_{rih} \le 1, \qquad i\in W, h\in H_i \tag{1}$$

$$\sum_{h\in H_i} Q_{ih} x_{rih} - \sum_{\substack{j\in W\\ j\neq i}}\sum_{h\in H_i} y_{rijh} + \sum_{\substack{j\in W\\ j\neq i}}\sum_{h\in H_i} z_{rjih} \ge D_{ir}, \qquad i\in W, r\in R \tag{2}$$

$$\sum_{\substack{j\in W\\ j\neq i}} y_{rijh} \le U_{ihr} x_{rih}, \qquad i\in W, h\in H_i, r\in R \tag{3}$$

$$z_{rijh} \le x_{rih}, \qquad i\in W, i\neq j h\in H_i, r\in R \tag{4}$$

$$z_{rijh} \le M_{ihr}, \qquad i\in W, i\neq j h\in H_i, r\in R \tag{5}$$

$$x_{rih} \ge 0, x_{rih}: integer, \qquad i\in W, h\in H_i, r\in R \tag{6}$$

$$y_{rijh} \ge 0, y: integer, \qquad i\in W, i\neq j h\in H_i, r\in R \tag{7}$$

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

Methodologies

Max-min

$$\boldsymbol{Maximize\ a}$$
$$\text{s.t. } \boldsymbol{Z_1 \ge a}$$
$$\boldsymbol{Z_2 \ge a}$$
$$\dots$$
$$\boldsymbol{Z_m \ge a}$$
$$\boldsymbol{where\ a = Min(Z_1, Z_2, \dots, Z_m)}$$

Max-sum

$$\boldsymbol{Maximize = Z_1 + Z_2 + Z_3 + \cdots + Z_m}$$

Shapley Value

$$\emptyset_i(c) = \sum_{S\subseteq N,\, i\in S} \frac{(|S|-1)!\,(|N|-|S|)!}{|N|!}\left[s(S) - c\left(\frac{S}{i}\right)\right]$$

Figures

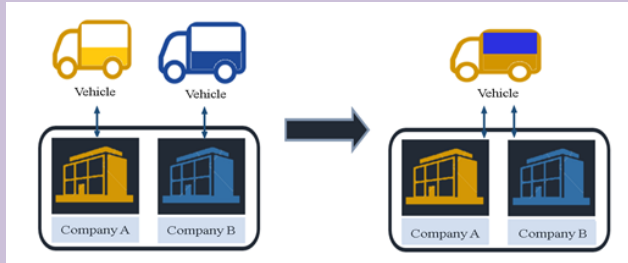

Figure 1. Operation of Refrigerated Logistics Warehouse Sharing Logistics System

Tables

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)	2,473

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

Table 3. No Collaboration and Minmax, Minsum cost

(Unit: 10$)

Solution	Company	Cost			Total
		A	B	C	
No Collaboration		43,310	31,310	27,650	102,270
Min ax		32,481	32,481	32,481	97,443
Minsum between two Companies	A, B	35,859	36,399	0	72,258
	A, C	34,032	0	30,032	63,664
	B, C	0	21,330	27,650	56,664
Minsum Full Collaboration	A, B, C	30,729	37,729	26,729	95,279

Table 4. Marginal Contribution by Inter-Company Partnerships

(Unit: 10$)

Solution	Company	Subgroup output	Marginal contribution		
			A	B	C
No Collaboration	A, B, C	0	0	0	0
Collaboration between two Companies	A, B	8,082	8,082	8,082	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	13,992	6,696	5,696	4,930
Column Sum			14,375	12,875	11,726
Shapley Value			4,792	4,292	3,909

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 Min-max criterion are often used a lot, this study also applied the Min-sum criterion and compared it. By applying Min-sum and Min-max, the total cost of partnership was reduced compared to when cold storage companies operate on their own without partnership.

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.