중핵을 이용한 공유 경제 기반 택배 네트워크 설계

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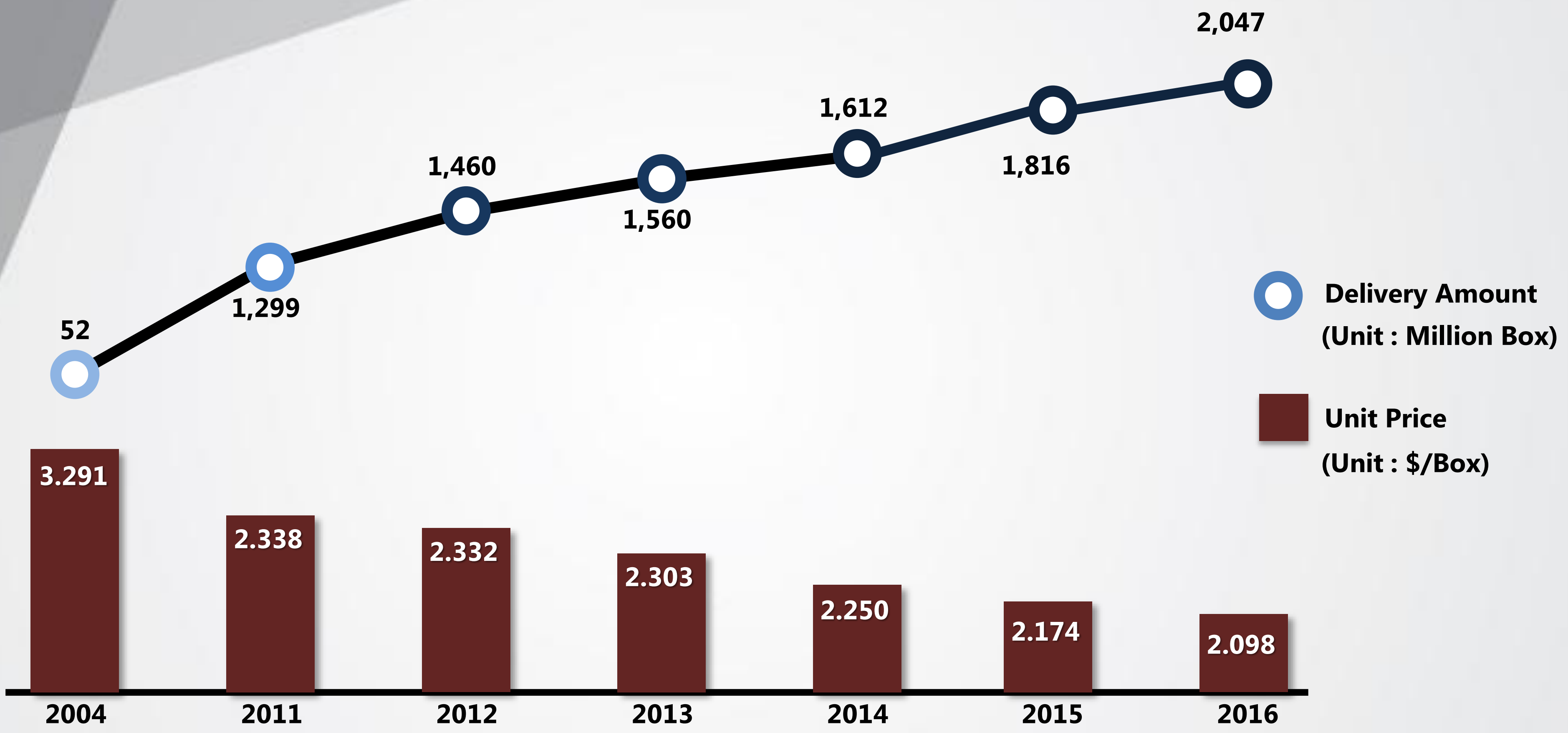
Trend for Express Delivery Service Market in Korea



Source : KILA(Korea Integrated Logistics Association)

Express Delivery Service in Korea

Rapid Increase	Severe Competition
Increase in customer demand for "Door-to-Door" delivery service Growth in the indirect purchase market	Saturated Market Competition for maximization of customer satisfaction Net profit decreases according to decrease in unit delivery price

This study suggests a sustainable collaboration model for increasing the competitiveness of each participating company

Literature Review

Category	Researcher
Express Delivery Service	Leung et al. (1990)
	Cheung et al. (2001)
	Ko et al. (2007)
Strategic Alliance	Parise and Henderson (2001)
	Perks and Easton (2000)
	Büyüközkan et al. (2008)
	Cho (2007)
	Chopra and Meindl (2004)
	Min (1996)
	Simchi-Levi et al. (2003)
	Cachon and Lariviere (1999)
Strategic Alliance in Express Delivery Service	Chung et al. (2009)
	Chung et al. (2010)
	Chung et al. (2011)
	Ferdinand et al. (2012)
	Ferdinand et al. (2013)

1. Service Center Level Collaboration Model

A strategic alliance model with regional monopoly of service centers

2. Weak Consolidation Terminal Level Collaboration Model

Compromised network design model for the strategic alliance of service centers and consolidation terminals

3. Strong Consolidation Terminal Level Collaboration Model

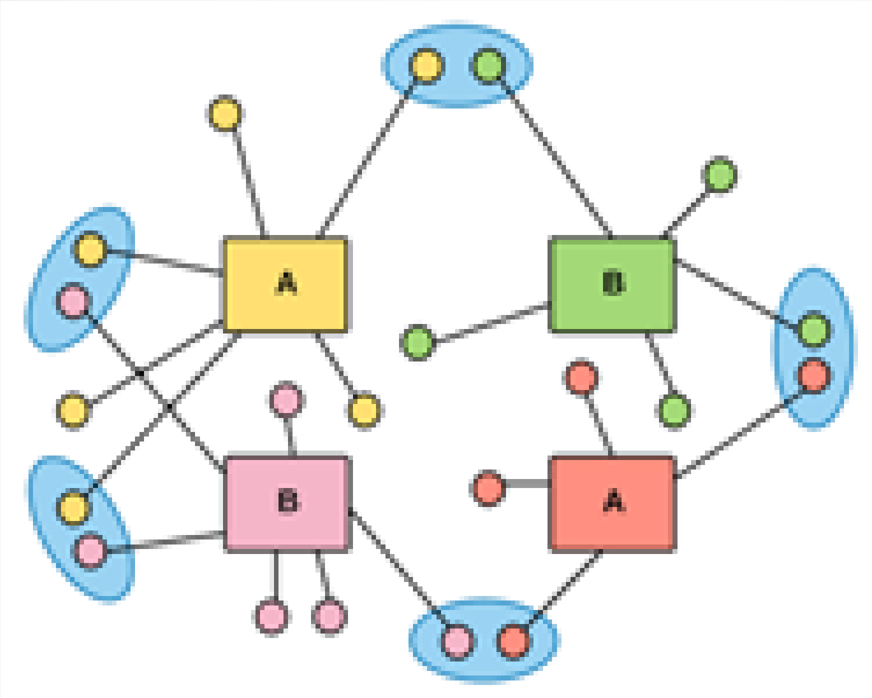
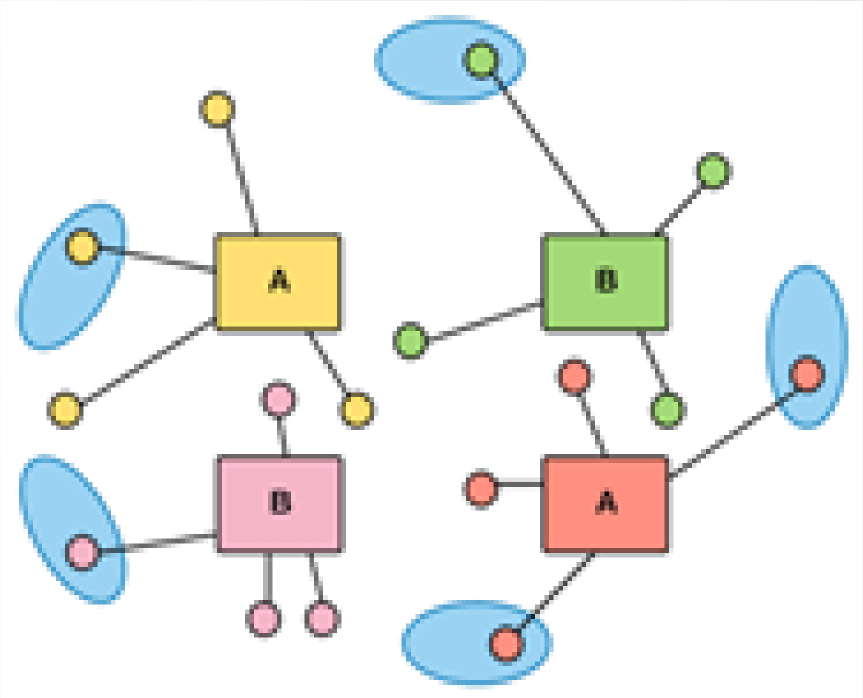
Multi-objective decision making model for strategic alliance

4. Extended Consolidation Terminal Level Collaboration Model

Collaborative system design: formulation and solution

- Model 1
- Profit Allocation by Nucleolus

Service Center Level Collaboration Model

Before	After
	

Problem Description

Objective

Construct a strategic alliance model with the objective of maximizing the net profit of each participating company

Determine how to allocate coalition profits to each company

Assumption

Usually only a single service center can be open in most of candidate merging regions and all the other service centers are closed within a merging region after alliance

The delivery amounts of the closed service centers within the same merging region are all assigned to the open service center after alliance

The processing capacity of the terminal for each company should be satisfied for alliance

Notation

I : set of express courier companies, $I = \{1, 2, \ldots, m\}$

J : set of service center regions for merging, $J = \{1, 2, \ldots, n\}$

T_i : set of company i 's terminals, $i \in I$

J_{ik} : set of service regions allocated to company i's terminal k

d_{ij} : daily delivery amount of company i within the merging region j

D_j : sum of daily delivery amount of all the service centers within region j

r_{ij} : revenue that company i obtains by delivering one unit within region j

c_{ij}^1 : unit delivery cost when company i's service center exists in the merging region j

c_{ij}^2 : unit delivery cost when company i's service center does not exist in the merging region j

Notation

Q_{ik} : delivery processing capacity remaining at terminal k of the company i

f_{ij} : daily fixed cost for operating the service center when company i 's service center exists in the merging region j

a_{ij} : index representing that $a_{ij} = 1$, if company i 's service center exists in the merging region j before alliance, $a_{ij} = 0$, otherwise.

(Decision Variable)

x_{ij} : binary variables such that $x_{ij} = 1$, if company i 's service center in the merging region j is still open after alliance, $x_{ij} = 0$, otherwise.

Net profit of company i after alliance

(Case 1) There is no existing service center within the region

$$c_{ij}^2 - r_{ij}$$

(Case 2) There is existing service center within the region

(1) After the alliance, service center is closed and consolidated into other company's service center $(x_{ij} = 0)$

$$-(r_{ij} - c_{ij}^1)d_{ij} + f_{ij}a_{ij}$$

(2) After the alliance, service center is open $(x_{ij} = 1)$

$$(r_{ij} - c_{ij}^1)(D_j x_{ij} - d_{ij}) + f_{ij}(1 - x_{ij})$$

Company *i*'s net profit reflecting (Case 1) and (Case 2) simultaneously

$$\sum_{j \in J}(r_{ij} - c_{ij}^1)a_{ij}(D_j x_{ij} - d_{ij}) + j \in J \sum f_{ij}a_{ij}(1 - x_{ij}) + \sum_{j \in J}(c_{ij}^2 - r_{ij})d_{ij}(1 - a_{ij})$$

Mathematical Formulation

(P)

$$Max\ z_1 = \sum_{j \in J} (r_{1j} - c_{1j}^1) a_{1j} (D_j x_{1j} - d_{1j}) + j \in J \sum f_{1j} a_{1j} (1 - x_{1j}) + \sum_{j \in J} (c_{1j}^2 - r_{1j}) d_{1j} (1 - a_{1j})$$

$$\vdots$$

$$Max\ z_m = \sum_{j \in J} (r_{mj} - c_{mj}^1) a_{mj} (D_j x_{mj} - d_{mj}) + j \in J \sum f_{mj} a_{mj} (1 - x_{mj}) + \sum_{j \in J} (c_{mj}^2 - r_{mj}) d_{ij} (1 - a_{mj}) \qquad (1)$$

$s.t$

$$\sum_{i \in I} x_{ij} = 1, \qquad i \in I \qquad (2)$$

$$x_{ij} \le a_{ij} \qquad i \in I, j \in J \qquad (3)$$

$$\sum_{j \in J_{ik}} (D_j x_{ij} - d_{ij}) \le Q_{ik}, \qquad i \in I, k \in T_i \qquad (4)$$

$$x_{ij} \in \{0,1\}, \qquad i \in I, j \in J \qquad (5)$$

Solution Procedure

Maxisum Criterion

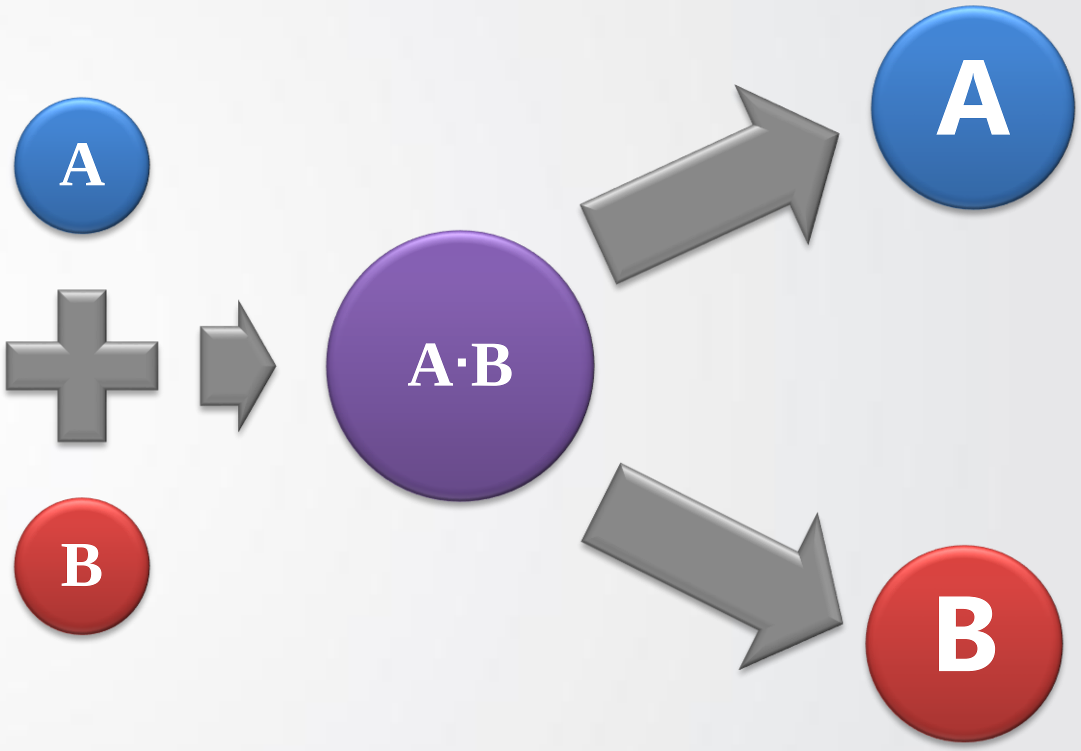
$$Maximize \quad Z_1 + Z_2 + \cdots + Z_m$$

Maximin Criterion

$$\alpha = Min(Z_1, Z_2, \ldots, Z_m)$$

$$\begin{aligned} & Max\ \alpha \\ & s.t. \quad Z_1 \geq \alpha \\ & \qquad\ \ Z_2 \geq \alpha \\ & \qquad\quad \vdots \\ & \qquad\ \ Z_m \geq \alpha \end{aligned}$$

Shapley value vs. Nucleolus



Shapley value allocation is known as
"The most equitable profit sharing method in cooperative game theory"

Concept to distribute synergies obtained through the coalition according to the marginal contribution of game participants

Core vs. Nucleolus

Completeness: Profits are entirely divided into participating company classes

Rationality: By joining the grand coalition, company classes do not receive less than they would if they chose to be part of any smaller coalition of company classes

Marginality: Company classes are provided at least enough to cover their marginal profits.

Numerical Example

- Three delivery service companies
- Each company has two terminals
- 10 merging regions are considered

Table 1. Data for Type I service centers

Merging region	delivery amount			Allocated terminal			Daily fixed cost		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
1	29	45	37	1	3	6	77	91	89
2	22	17	29	1	3	6	97	79	79
3	46	30	40	1	4	6	89	67	83
4	10	26	27	2	4	6	81	86	61
5	48	42	19	2	3	5	66	54	-
6	47	42	35	1	4	5	64	62	-
7	29	14	37	2	4	6	67	-	94
8	25	18	23	1	3	6	82	-	63
9	20	36	29	2	3	5	-	77	90
10	23	50	42	2	4	5	-	80	52

* C1: Company1, C2: Company 2, C3: Company 3

Table 2. Remaining capacity of terminal

Terminal	Capacity
1	145
2	137
3	112
4	162
5	129
6	106

Numerical Example

Optimal Solution for Maxmin Criterion

	1	2	3	4	5	6	7	8	9	10
x_{1j}	1	1	0	0	1	0	1	0	0	0
x_{2j}	0	0	1	0	0	1	0	0	1	0
x_{3j}	0	0	0	1	0	0	0	1	0	1

C1 = $450, C2 = $443, C3 = $442, Total = $1,345

Optimal Solution for Maxsum Criterion

	1	2	3	4	5	6	7	8	9	10
x_{1j}	1	0	0	0	0	0	1	0	0	0
x_{2j}	0	1	1	0	1	1	0	0	1	0
x_{3j}	0	0	0	1	0	0	0	1	0	1

C1 = $436, C2 = 487, C3 = 442, Total = $1,365

Table 3. Maxmin vs. Maxsum Criteria

		SUM	1	2	3
Maxmin		1,335	450	443	442
Maxsum	1		0		
	2			0	
	3				0
	1+2	606	278	328	
	1+3	678	396		282
	2+3	638		304	344
	1+2+3	1,365	436	487	442

Table 4. Shapley value allocation

Combination for alliance			Marginal contribution		
			1	2	3
No alliance	1, 2, 3 ①		0	0	0
Alliance between two Companies	1+2	606	606	606	
	1+3	678	678		678
	2+3	638		638	638
	Average ②		642	622	658
Full alliance	1+2+3③	1,365	727	687	759
Shapley Value	(①+②+③) / 3		**456.3**	**436.3**	**472.3**

Maximize t

Subject to

$$R_1 \geq C_1 + t$$

$$R_2 \geq C_2 + t$$

$$R_3 \geq C_3 + t$$ **(Rationality)**

$$R_1 + R_2 \geq C_{12} + t$$

$$R_1 + R_3 \geq C_{13} + t$$

$$R_2 + R_3 \geq C_{23} + t$$

$$R_1 + R_2 + R_3 = C_{123}$$ **(Completeness)**

$$R_1, R_2, R_3, t \geq 0$$

Nucleolus-based allocation
$\boldsymbol{R_1 = 457.3}$, $\boldsymbol{R_2 = 417.3}$, $\boldsymbol{R_3 = 489.8}$

Numerical Example

	Maxmin		Maxsum		Shapley value		Nucleolus	
Company 1	$450	34%	$436	31%	$456.3	34%	$457.3	33%
Company 2	$443	33%	$487	36%	$436.3	31%	$417.3	31%
Company 3	$442	33%	$442	33%	$472.3	35%	$489.8	36%
Total	$1,335		$1,365		$1,365		$1,365	

Maxmin Criterion : Small profit ($1, 335), but well balanced (imbalance range : 1%)

Maxsum Criterion : Large profit ($1,365), but imbalance (imbalance range : 5%)

Shapley Value : Large profit ($1,365), and small imbalance (imbalance range : 4%)

Nucleolus : Large profit ($1,365), and small imbalance (imbalance range : 1%)

Conclusions

Contribution

Win-win strategy through increasing net profit of each participating company

Sustainable coalition

Further Research Areas

Consider delivery service reliability

Develop coordinating policy

Extend to other collaboration models

Apply various methodologies of coalitional game theory to strategic alliance