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협업 기반 배송 서비스 네트워크에 대한 동적 설계

Dynamic design for collaborative delivery services

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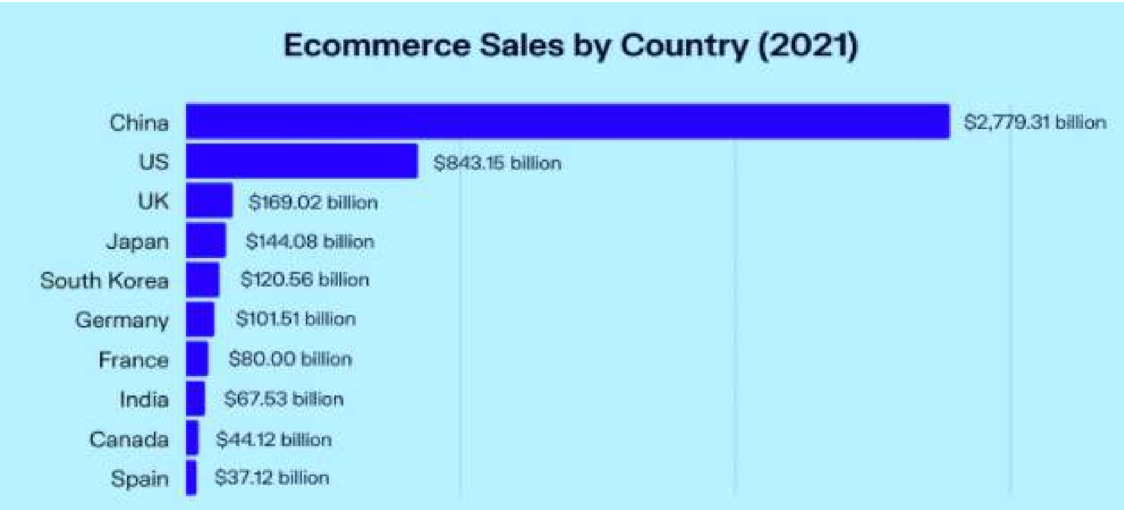
Contents

Introduction

Global e-commerce penetration rate in 2021



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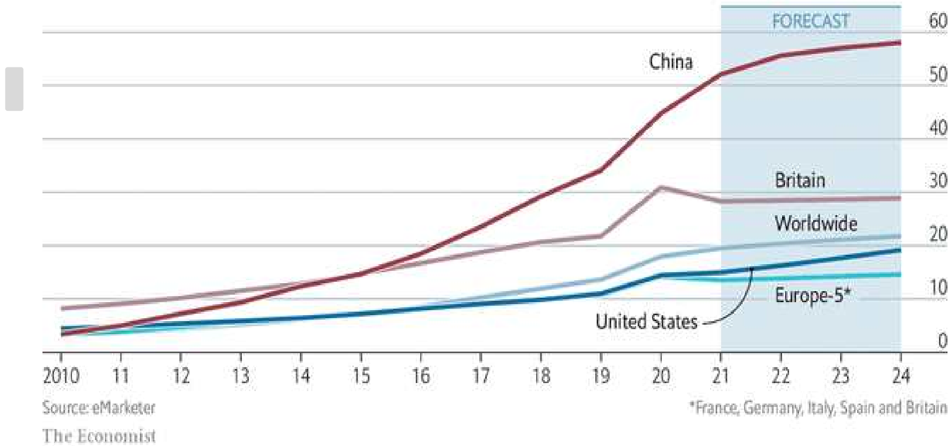


Online retail sales as of % of total (Source: The Economist, March 2021)

Introduction

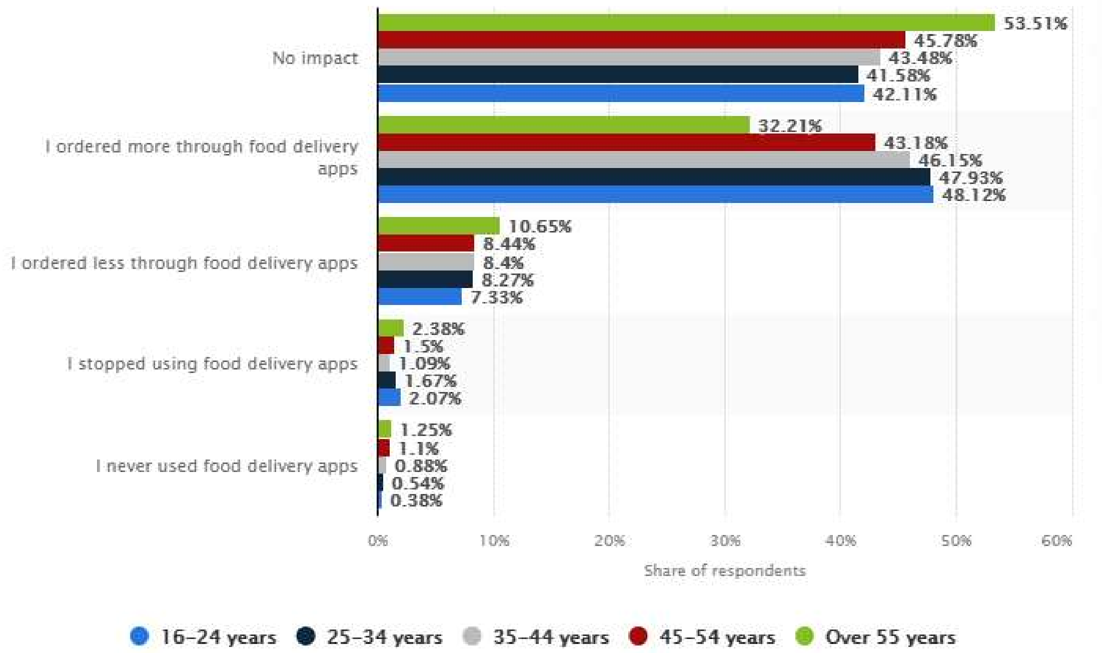
Reasons for increase in contactless consumption

- **Effects of Coronavirus Pandemic on Parcel Delivery Businesses**

COVID-19 IMPACT	DATA INDICATORS
• **Digitalisation:** With high internet and smartphone penetration, consumers have a chance to be familiar with online shopping in this pandemic situation • **Government recommendation:** To prevent the spread of COVID-19, the government recommends staying at home, which leads to reduced footfall at offline shopping malls • **Consumer sentiment:** With increased unemployment, people are more cautious about their spending	**43.7%** Of South Korean consumers make orders at any time from anywhere in 2020 **22.1%** Of South Korean consumers think online shopping is easy and has extensive reach in 2020 **27.9%** Of South Korean consumers would like to visit shopping malls, which decreased by 5% from 2019(32.9%)

Introduction

- **<u>Effects of Coronavirus Pandemic on Parcel Delivery Businesses</u>**



Impact of COVID-19 (coronavirus) pandemic on food delivery app usage in South Korea as of June 2020, by age group

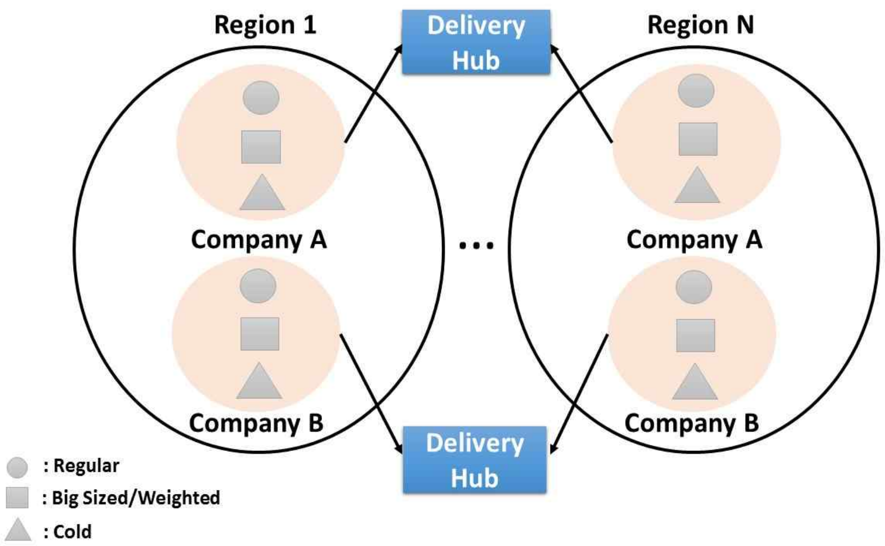
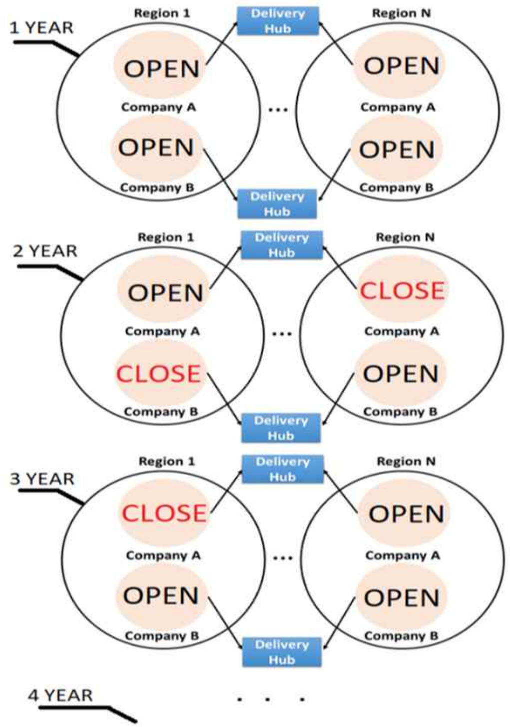
Introduction

Literature review

Category	Previous studies
Parcel Delivery Service	Lenz et al. (2004)
	Lierow et al. (2013)
	Ko et al. (2007)
Last-mile delivery	Galkin et al. (2019)
	Giret et al. (2018)
	Kanuri et al. (2019)
	Clausen et al. (2016)
	Manerba et al. (2018)
	Ko et al. (2018)
Collaboration	Chung et al. (2016)
	Wang et al.(2018)
	Gansterer and Hartl (2017)
	Yea et al (2018)
	Timmer et al.(2013)
	Do et al.(2019)
	Villamizar et al.(2015)

Problem Description

Dynamic design for collaborative delivery services

Before	After
	

Short-term collaboration

Temporal collaboration

Problem description

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

- Dynamic design for collaborative delivery services

Profit Allocation by Shapley Value and nucleolus based allocation

Mathematical Model

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

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

w_{kt} : weight for revenue per item with service class k during planning period t in delivery hub
r_{ijkt} : net profit contributed by one unit of demand with service class k of company i within region j during planning period t, $i \in I, j \in J, t \in T, k \in K$
s_{ijk} : set-up cost for service class k of company i within region j, $i \in I, j \in J, k \in K$
v_{ijk} : shut-down profit for service class k of company i within region j, $i \in I, j \in J, k \in K$

Decision variable:

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

Mathematical Model

Non-Linear model (P)

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

$$\vdots$$

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

$s.t.$

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

$$\sum_{j\in J}\sum_{k\in K} w_{kt}\left(D_{jkt}x_{ijkt} - d_{ijkt}\right) \le Q_{it} \qquad i\in I, t\in T$$

$$x_{ijk} \in \{0,\ 1\} \qquad i\in I, j\in J, k\in K, t\in T$$

Mathematical Model

The following new variables y and z are generated to linearize

$$y_{ijk,t,t+1} = x_{ijkt} \cdot (1 - x_{ijk,t+1})$$

$$z_{ijk,t,t+1} = x_{ijk,t+1} \cdot (1 - x_{ijkt})$$

x_{ijkt}	$x_{ijk,t+1}$	y
1	1	0
1	0	1
0	1	0
0	0	0

x_{ijkt}	$x_{ijk,t+1}$	z
1	1	0
1	0	0
0	1	1
1	1	0

Then we can linearize

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

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

Mathematical Model

Linear model (P2)

$$Max\ \phi_1(x) = \sum\sum\sum(r_{1jkt}D_{jkt} - f_{1jkt})x_{1jkt} + \sum\sum(f_{1jkt} - r_{1jkt}d_{1jkt}) + \sum^{l-1}\sum\sum\{s_{1jk}\cdot y_{1jkt,t+1} - v_{1jk}\cdot z_{1k,t+1}\}$$

$$\vdots$$

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

$s.t.$

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

$$\sum_{j\in J}\sum_{k\in K} w_{kt}\left(D_{jkt}x_{ijk} - d_{ijkt}\right) \le Q_{it} \qquad i\in I,\ t\in T$$

$$y_{ijk,t,t+1} \le \frac{x_{ijkt} - x_{ijk,t+1} + 1}{2} \qquad i\in I, j\in J, k\in K, t\in T$$

$$z_{ijk,t,t+1} \le \frac{1 - x_{ijkt} - x_{ijk,t+1}}{2} \qquad i\in I, j\in J, k\in K, t\in T$$

$$x_{ijk} \in \{0,\ 1\} \qquad i\in I, j\in J, k\in K, t\in T$$

Solution Procedure

Profit allocation

Max-min Criterion

$$\boldsymbol{Maximize}\ \alpha$$

Subject to

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

Max-sum Criterion

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

Shapley Value

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

Nucleolus

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 most their marginal profits.

Numerical Example

- 3 delivery service companies
- 4 merging regions
- 1 service class

Remaining capacity of terminal

Terminal	Capacity
1	480
2	430
3	525

Data for delivery demand

	Years	R_1	R_2	R_3	R_4
	1st	51	85	58	20
C_A	2nd	85	22	96	26
	3rd	72	36	54	75
	1st	15	63	34	85
C_B	2nd	25	93	45	26
	3rd	43	64	74	35
	1st	19	87	72	57
C_C	2nd	26	62	36	85
	3rd	75	22	88	76

Data for daily fixed cost.

	Years	R_1	R_2	R_3	R_4
	1st	83	68	52	214
C_A	2nd	196	201	261	259
	3rd	83	225	271	293
	1st	130	168	272	111
C_B	2nd	127	86	185	275
	3rd	236	50	67	104
	1st	136	121	64	79
C_C	2nd	132	69	298	227
	3rd	89	140	175	258

Conclusion

Contribution

- Win-win strategy through increasing net profit of each participating company considering long-term collaboration
- Sustainable coalition

Further Research Areas

- Robust design for collaboration
- Collaborative operation among fulfillment centers