Designing in-store fulfillment network in the omnichannel retail environment

2017. 11. 02
SCM 공개발표

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Omni-channel retail environment in Korea

Customers have gotten used to purchasing goods across channels

Merchandisers have gradually combined their own multiple channels or cooperated with others to achieve omni channel

The growth rates of transaction value of on/offline hybrid mall

Just 20.8% of same-day delivery service

The increase of holding plus backorder costs in stores

From: the report of Yonhap New Agency

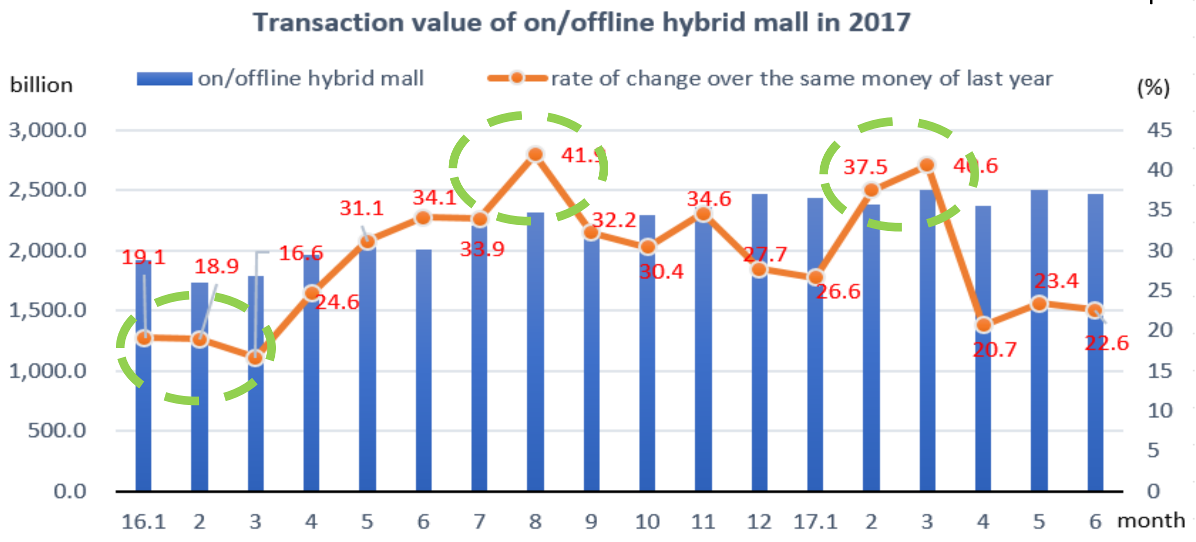


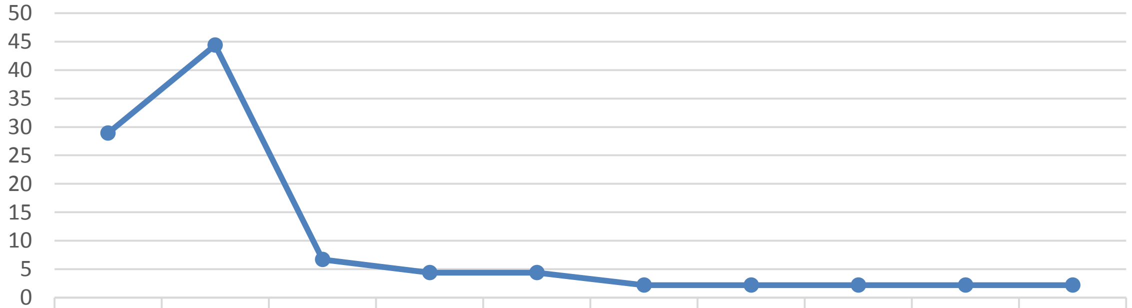
Fig.1. Transaction value of on/online hybrid mall in 2017

From: Koreans statistical information service

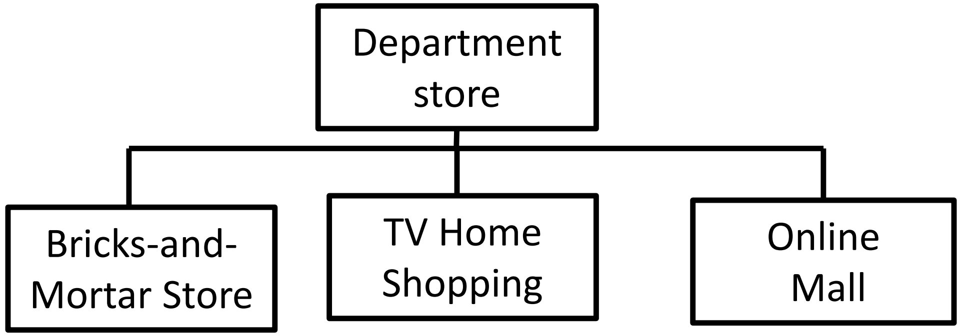
Clothing market in Korea

- Clothing are sold from various retail distribution channels, like department store, outlet, supermarket, department mall, online shopping mall.
- Customers can browse more times before buying clothes than others.
- Department stores actively improve omni-channel measures, but all of suppliers don’t follow the sale model.
- In the agency-selling mode, forcing suppliers to cut down the price or join promotion activities could possibly ruin the relationship between suppliers and department stores
- On the contrary, it is possible that parts of popular products haven’t the omni-channel service (buy online, pickup in store/fast delivery out of store sites)

Product types that customers prefer of browsing more times with multiple channels and buying



	Digital products	Garment and Shoes	Cosmetics	Furniture	Food	Exerciser	Auto spare parts	Book	Accessory	Baby milk powder
%	28.9	44.4	6.7	4.4	4.4	2.2	2.2	2.2	2.2	2.2



facilitating Omni-channel Actively

Lotte, Shinsegae, Hyundai

From:크로스태널_소비_탐색적연구_소비문화연구

Omni-channel logistics

Outline of Omni-channel logistics

Source: Retail logistics in the transition from multi-channel to omni-channel

- Predictive customer analysis
  Customer purchasing behavior
  Right products types in right places
- In-store delivery network
  Online and in-store demand state(standard deviation)
  Density of demand locations

(1)

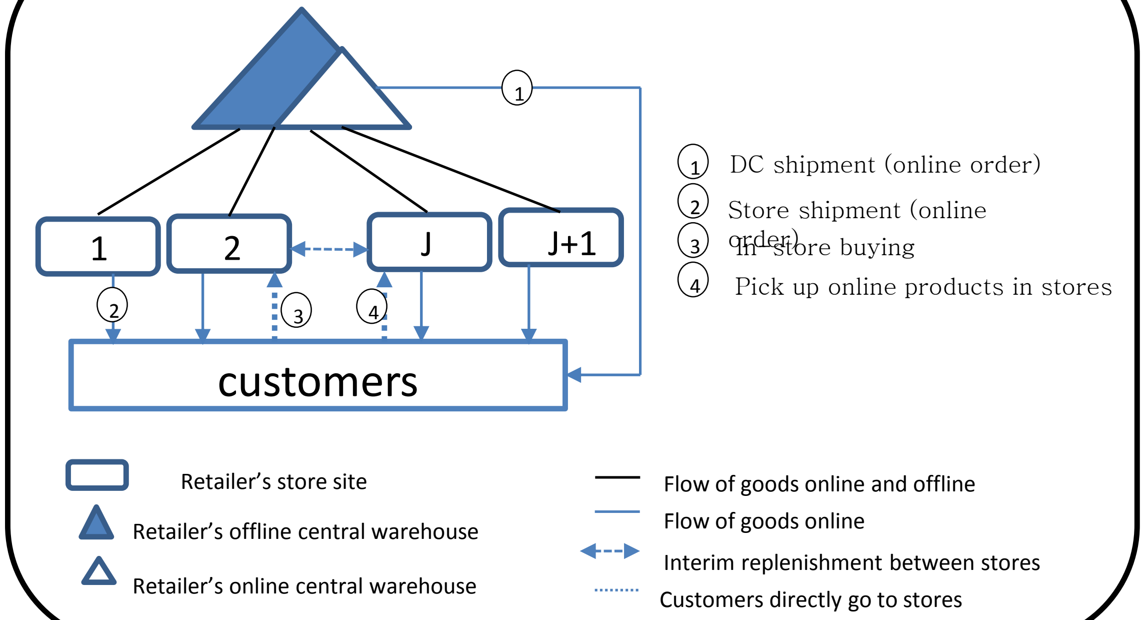
Predictive Customer Analysis

Data mining level: Select out parts of online product types that often need picking up in stores or fast delivery in terms of transaction data and some previous studies

Network level: Discover the association rule between popular products and customer geographic locations

(2)

In-store delivery network

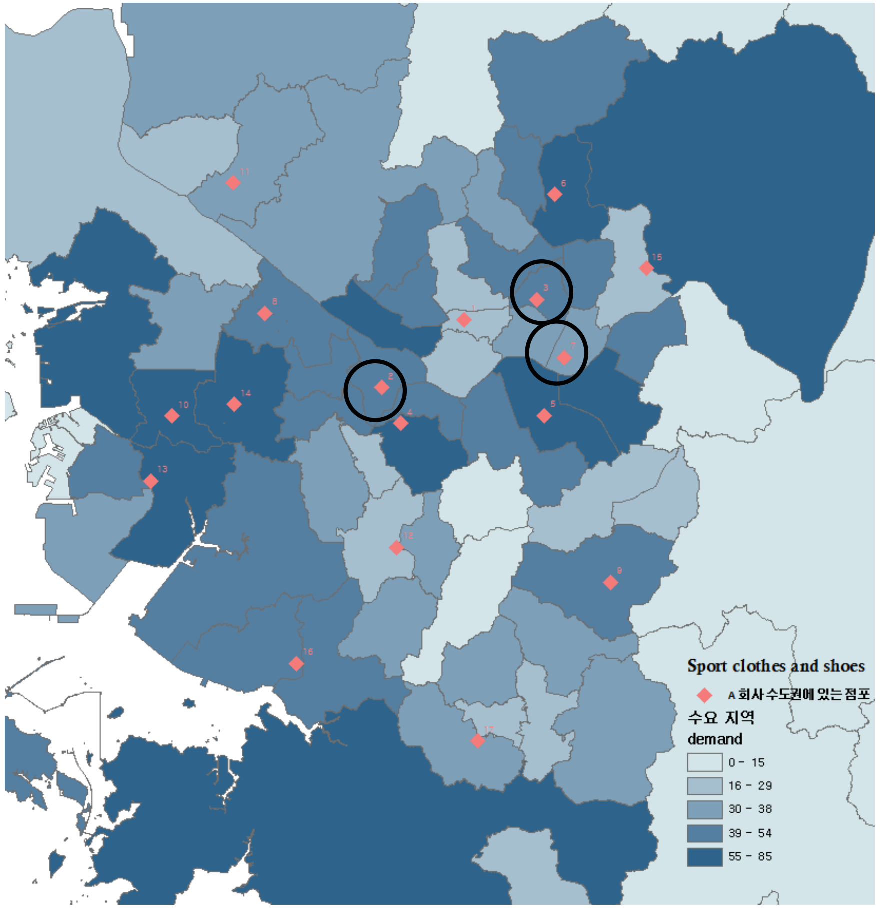


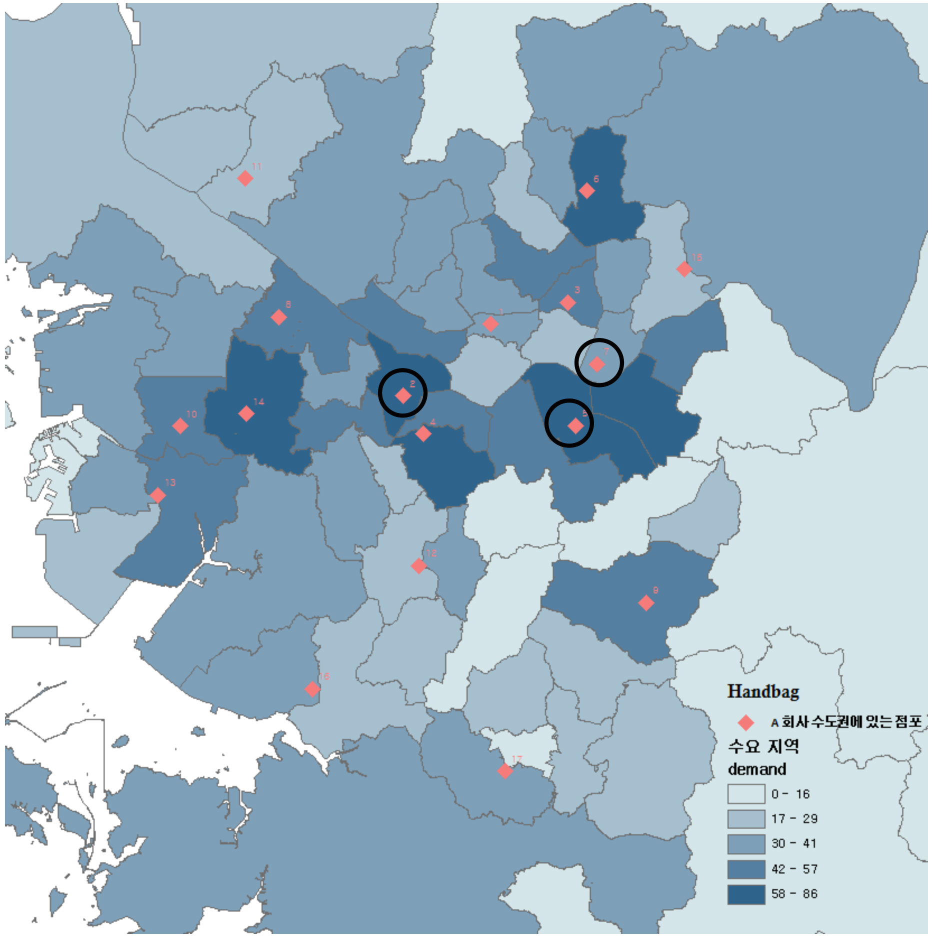
How to design in-store fulfilment network

- Omnichannel sales grows, but profitability is still uncertain in Korean retailing.
- Retailers and Suppliers have realized high investment cost on designing their omni-channel distribution network

Objective

Designing in-store fulfillment network to satisfy omni-channel retail market in term of predictive customer analysis





- Expected Online demand quantity of two products is similar.
- Standard deviation of A online products is higher than B's
- Stores marked by black circles have the attributes of high standard deviation
- In Annual season

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Previous Literature

Title	Author	Detail
A GA-based optimisation model for big data analytics supporting anticipatory shipping in Retail 4.0	Lee, C. K. H. (2016).	It converts the concept of anticipatory shipping into the magnitude. Cluster-based association rule mining is applied to discover the purchase pattern and a genetic algorithm optimisation model is applied to trade off different factors (transportation cost, time, prediction rule confidence) in anticipatory shipping
Managing Multi- and Omni-Channel Distribution: Metrics and Research Directions	Ailawadi & Farris, 2017	It offers the performance metrics to assess the effectiveness of Omni-channel distribution management for both suppliers and retailers
Product whole life-cycle and omni-channels data convergence oriented enterprise networks integration in a sensing environment	Li et al., 2015	Inter enterprise collaboration should meet the new challenges of omni-channel marketing, closed-loop supply chain and enterprise networks integration. In the process, data convergence is a key issue.
The value of virtual pooling in dual sales channel supply chains	Mahar et al., 2009	The authors invested how selecting inventory positions (store hubs and depots) under the circumstance of dynamic online demands can provide more economic benefits and develop two dynamic assignment polices.
Retail logistics in the transition from multi-channel to omni-channel	Hübner, Wollenburg, et al., 2016	The paper overally clear up the transition of retail logistics from separate multi-channel to integrated omni-channel fulfillment.
Integration of Online and Offline Channels in Retail: The Impact of Sharing Reliable Inventory Availability Information	S.a & A.b, 2014	Through analyzing the chanage of online and offline sale and inventory information, the authors confirm BOPS implementation results in lower online sales, higher store sales, and higher store traffic and ROPO increases the rate that customers buy in the stores.

The distinctiveness of the research

The Summary of Previous Literature

- Previous literatures have stated that omni-channel distribution is an inevitable trend.
- The literatures based on the whole view to research Omni-channel delivery network, like multi-period one or statics and dynamic assignment have been more issued, but those based on multiple products are scarce.

The distinctiveness

- This research attempts to evaluate how different attribution (density of demand locations, standard deviation of online sales) of product types with the increase of online sales shipped by stores plays a critical role in determining the number of store sites providing e-fulfillment.
- It will give merchandisers several sights on how to control holding plus backorder costs of stores when stores fulfill online demands

Research Process

STEP 1	**Predictive Customer Analysis**	• Selecting out several product types fit to omnichannel service • Getting the proportion per product type per demand location by data mining • Classifying five levels based on online order quantities • Predicting online demand per product type and standard deviation for various demand levels
STEP 2	**In-store Delivery Network**	• Network of single product type 1. Just satisfying high demand locations taking up 30% of total online requirements 2. Satisfying multiple locations taking up 60% of total online requirements 3. There are 5 stages (online demand satisfied by stores increases) in 1 and 6 stages in 2. Quantity per stage in 1 is as similar as one in 2 • Network of multiple product types 1. Satisfying multiple locations taking up 60% of total online requirements
STEP 3	**Branch-and-Bound Algorithm**	• Minimizing holding plus backorder cost with maximizing standard deviation on in-store and online demand • Verifying rationality of the algorithm by computer programming

Static in-store delivery model

Minimize

$$\sum_{i=1}^{I} f_i \cdot x_i + \sum_{p=1}^{P}\sum_{i=1}^{I}\sum_{j=1}^{J} C_{ij}^{s} \cdot e_{pij} \cdot \mu_{pj}^{e} + \sum_{p=1}^{P}\sum_{i=1}^{I} C_{di}^{b} \cdot \mu_{pi} + l \cdot h \cdot \sum_{p=1}^{P}\sum_{i=1}^{I} \mu_{pi} +$$

$$\sum_{p=1}^{P}((h \cdot z_p + (h+p) \cdot R_{(z)p}) \cdot \sum_{i=1}^{I} \sqrt{(l+1) \cdot \sigma_{pi}^{2}})$$

Subject to

$$\sum_{i=1}^{I} e_{pij} = 1 \quad \text{for } j = 1, \cdots, J \text{ and } p = 1, \cdots, P \tag{1}$$

$$\sum_{p=1}^{P}\sum_{j=1}^{J} e_{pij} \leq M \cdot (1 + x_i) \quad \text{for } i = 1, \cdots, I \subset J \tag{2}$$

$$\sum_{p=1}^{P} e_{pij} \leq (J+1) \cdot e_{pii} \quad \text{for } i = 1, \cdots, I \subset J \text{ and } j = 1, \cdots, J \tag{3}$$

$$d_{ij} \cdot e_{pij} \leq d^{one} \quad \text{for } i = 1, \cdots, I \subset J,\ j = 1, \cdots, J \text{ and } p = 1, \cdots, P \tag{4}$$

$$CP_{pi} \geq \mu_{pi}^{s} + \sum_{j=1}^{J} e_{pij} \cdot \mu_{pj}^{e} \quad \text{for } i = 1, \cdots, I \subset J \tag{5}$$

$$x_i \in \{0,1\} \quad \text{for } i = 1, \cdots, I \subset J \tag{6}$$

$$e_{pij} \in \{0,1\} \quad \text{for } i = 1, \cdots, I \subset J,\ j = 1, \cdots, J \text{ and } p = 1, \cdots, P \tag{7}$$

$$y_{cw} \geq 0 \tag{8}$$

Quantities that are a function of the decision variables

- μ_{pij}^{e} Expected online demand of p product with service level in location j satisfied by store site i
- μ_{pi} Expected demand of p product per period of store site in location i for the whole demand location
- σ_{pi} Standard deviation of demand per period of store site in location i for the whole demand location

$$\mu_{pij}^{e} = \mu_{pj}^{e} \cdot SL_{pj}$$

$$\mu_{pi} = \mu_{pi}^{s} + \sum_{i=1}^{I} \mu_{pij}^{e} \cdot e_{pij}$$

$$\sigma_{pi}^{2} = \sigma_{pi}^{s\,2} + \sum_{i=1}^{I} (\sigma_{pi}^{e} \cdot e_{pij})^{2}$$

the unit Normal right-tail linear loss function of p product

$$Z_p = \frac{y_{cw} - (l+1)\sum_{i=1}^{I} \mu_{pi}}{\sqrt{(l+1)(\sum_{i=1}^{I} \sigma_{pi})^{2}}}$$

the unit Normal right-tail linear loss function of p product

$$R_{(z)p} = \frac{1}{\sqrt{2\pi}} \cdot e^{-\frac{z^2}{2}} - \frac{z}{2} + \frac{z}{2} \cdot \operatorname{erf}\left(\frac{z}{\sqrt{2}}\right)$$

Static in-store delivery model

Index

P	Index for interim popular product
i	Index for online demand location including store site
j	Index for online demand location

Decision variable

y_{cw}	Order-up-to-quantity at the central warehouse
x_i	Whether the store in location i is setup to fulfill online demand (x_i=1) or not x_i=0)
e_{pij}	Whether store site in location i satisfies p product type of online demand in location j (e_{pij}=1) or not (e_{pij}=0)

System parameters

μ^e_{pj}	Expected online demand of p product per period for the demand location j
μ^s_{pi}	Expected in-store demand of p product per period for the store in location i
σ^e_{pi}	Standard deviation of online demand of p product per period for the demand location j
σ^s_{pi}	Standard deviation of in-store demand of p product per period for the store in location i
ℓ	Lead time from the center warehouse to the stores
h	Holding cost per store site
f_i	Fixed cost of maintaining e-fulfillment capability at location i's store
C^s_{pi}	Transportation cost per unit for drawing it out of i store site and delivering to Customers in location j (small-size truck)
C^b_{di}	Transportation cost per unit of online and in-store products from the central warehouse to location i including one store site (big-size truck)
d_{ij}	The distance between store in location i and demand location j
d^{one}	The limitation of distance for same day delivery
CP_i	Capacity of the store in location i
SL_{pi}	The service level of p product in term of popular extent to product in location j

1. Solving nonlinear integer problem

LB1= Minimize $l \cdot h \cdot \sum_{p=1}^{P} \sum_{i=1}^{I} \mu_{pi} + \sum_{p=1}^{P} ((h \cdot z_p + (h+p) \cdot R_{(z)p}) \cdot \sum_{i=1}^{I} \sqrt{(l+1) \cdot \sigma_{\mathbf{pi}}^{2}})$

- Locating some store sites with the maximum standard deviation of in-store demand minimizes holding plus backorder (by solving a continuous problem)
- For some given nodes in the branch-and-bound tree, minimizing holding plus backorder costs by maximizing each node's standard deviation on the in-store and online demand

2. Solving linear integer problem

LB2= Minimize $\sum_{i=1}^{I} f_i \cdot x_i + \sum_{p=1}^{P} \sum_{i=1}^{I} \sum_{j=1}^{J} C_{ij}^{s} \cdot e_{pij} \cdot \mu_{pj}^{\mathbf{e}} + \sum_{p=1}^{P} \sum_{i=1}^{I} C_{di}^{b} \cdot \mu_{pi}$

- Calculating fixed, delivery and transportation cost in term of optimization of LB1

3. Recalculating total cost in the tree

- By the 1 and 2 step, we can get the basic value of branch and bound algorithm (B&B).
- The study construct the computer code about B&B by linear search (computing algorithm/선형탐색)

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Analysis on sports clothes and shoes

Single product

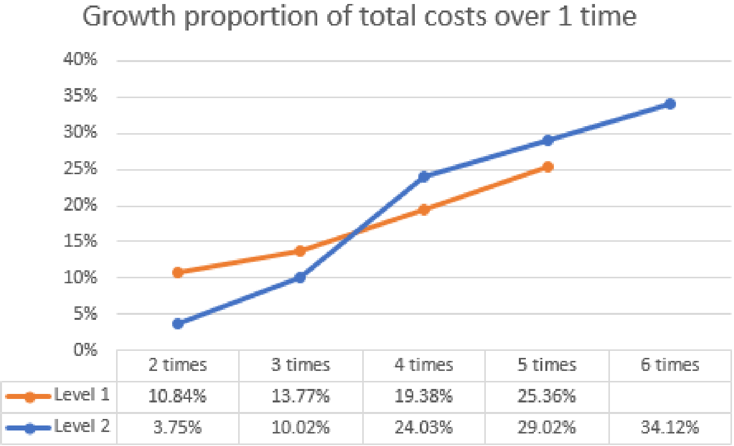
Total costs of level 1

	1 time	2 times	3 times	4 times	5 times
Total cost (unit 10000)	15754	17462	17924	18807	19749
Growth proportion		10.84%	13.77%	19.38%	25.36%
Number of stores	1	3	2	2	6

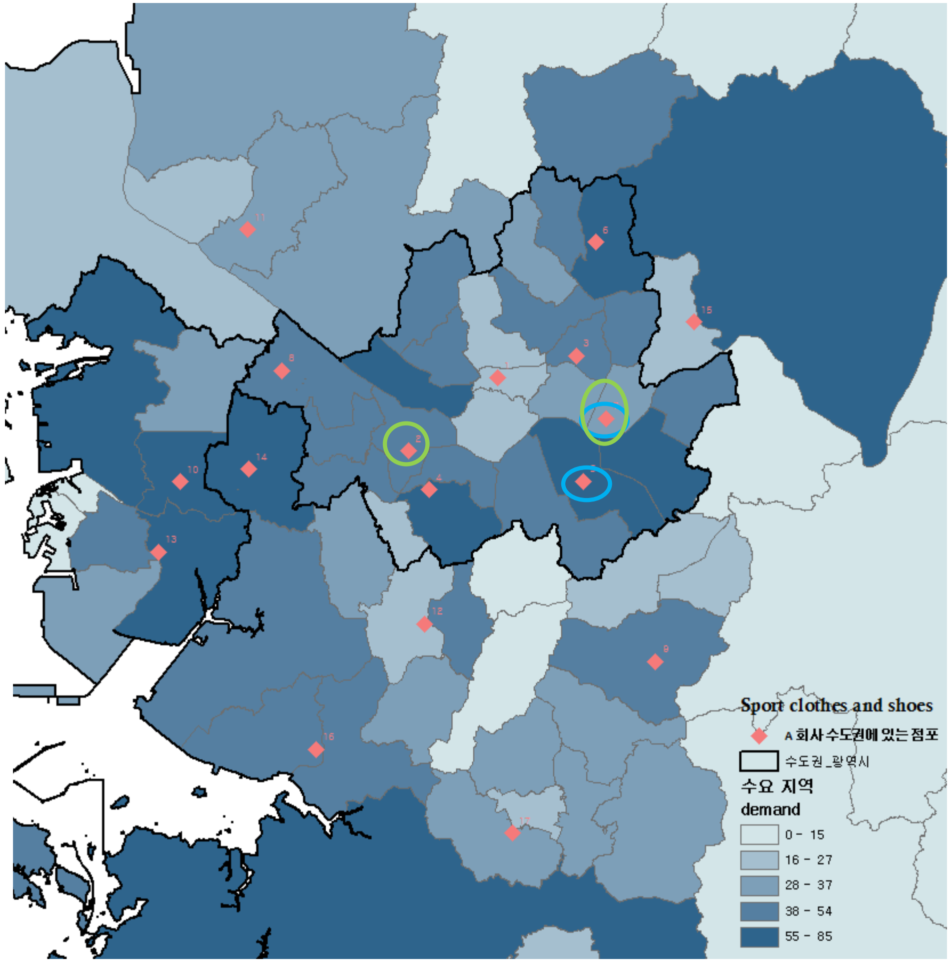
Total costs of level 2

(unit 10000)	1 time	2 times	3 times	4 times	5 times	6 times	7 times
Total cost	14514	15058	15968	18001	18726	19466	Nan
Growth proportion		3.75%	10.02%	24.03%	29.02%	34.12%	
Number of stores	1	1	2	2	2	2	

Unit 10000



	2 times	3 times	4 times	5 times	6 times
Level 1	10.84%	13.77%	19.38%	25.36%	
Level 2	3.75%	10.02%	24.03%	29.02%	34.12%



level 1

Just satisfying high demand locations taking up 30% of total online requirements

level 2

Satisfying multiple locations taking up 60% of total online requirements

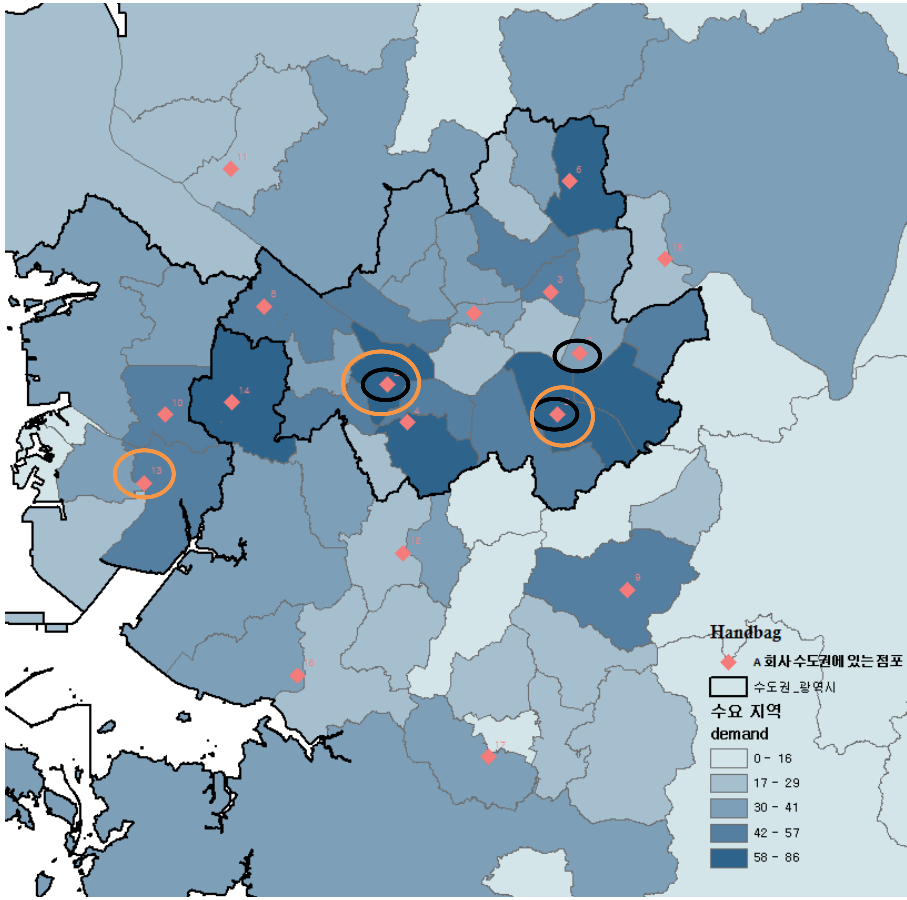
Analysis on handbag

Total costs of level 1

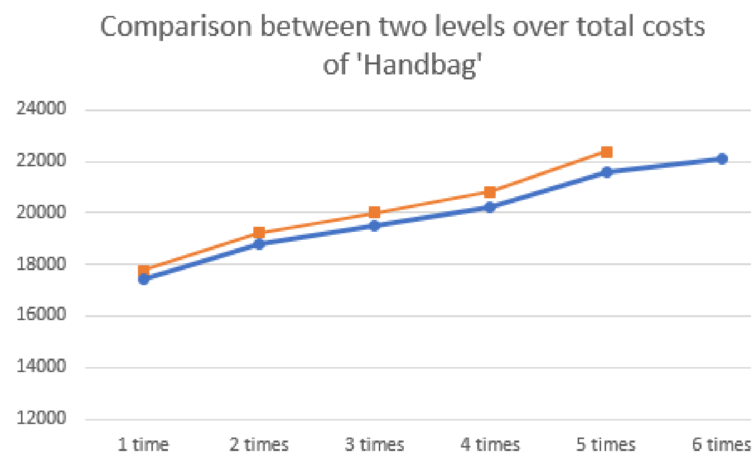
Level1	1 times	2 times	3 times	4 times	5 times
Total cost (unit10000)	17751	19237	20015	20834	22388
Growth proportion		8.37%	12.75%	17.37%	26.12%
Number of stores	1	2	2	3	3

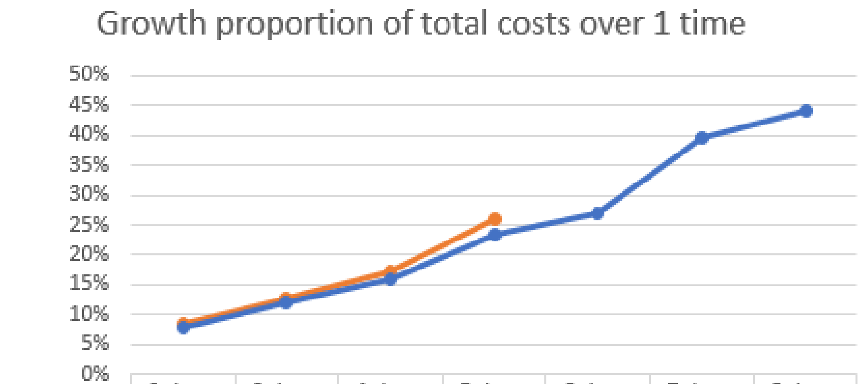
Total costs of level 2

Level2	1 time	2 times	3 times	4 times	5 times	6 times	7 times	8 times
Total cost (unit10000)	17448	18814	19520	20201	21553	22127	24361	25158
Growth proportion		7.83%	11.88%	15.78%	23.53%	26.82%	39.62%	44.19%
Number of stores	2	2	3	3	3	3	4	4



Unit 10000



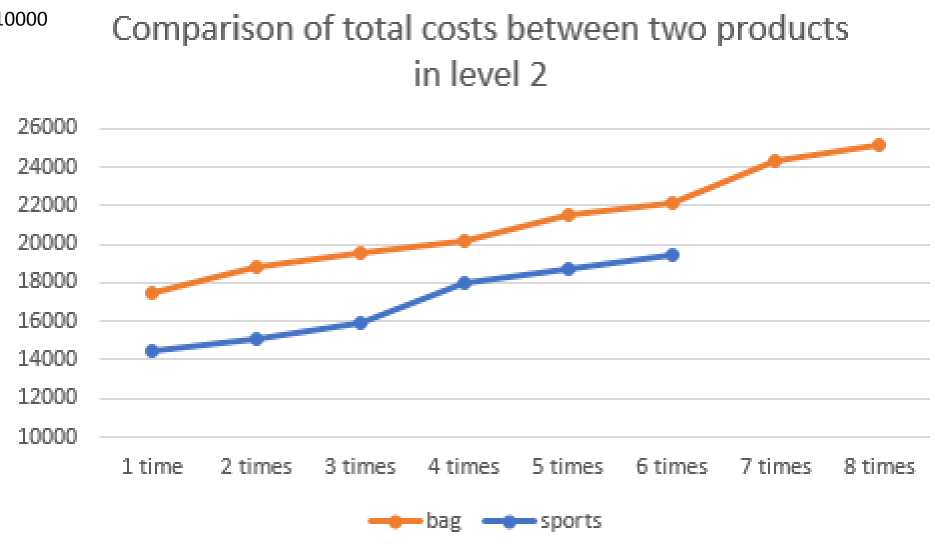


	2 times	3 times	4 times	5 times	6 times	7 times	8 times
Level1	8.37%	12.75%	17.37%	26.12%			
Level2	7.83%	11.88%	15.78%	23.53%	26.82%	39.62%	44.19%

(1)=level 1
(2)=level 2

Comparison between sport clothes and shoes & handbag in level 2

Unit 10000



'sport'

- Relative central distribution network in low stages
- Costs increase speedily in high stages for high standard deviation of online sale

'handbag'

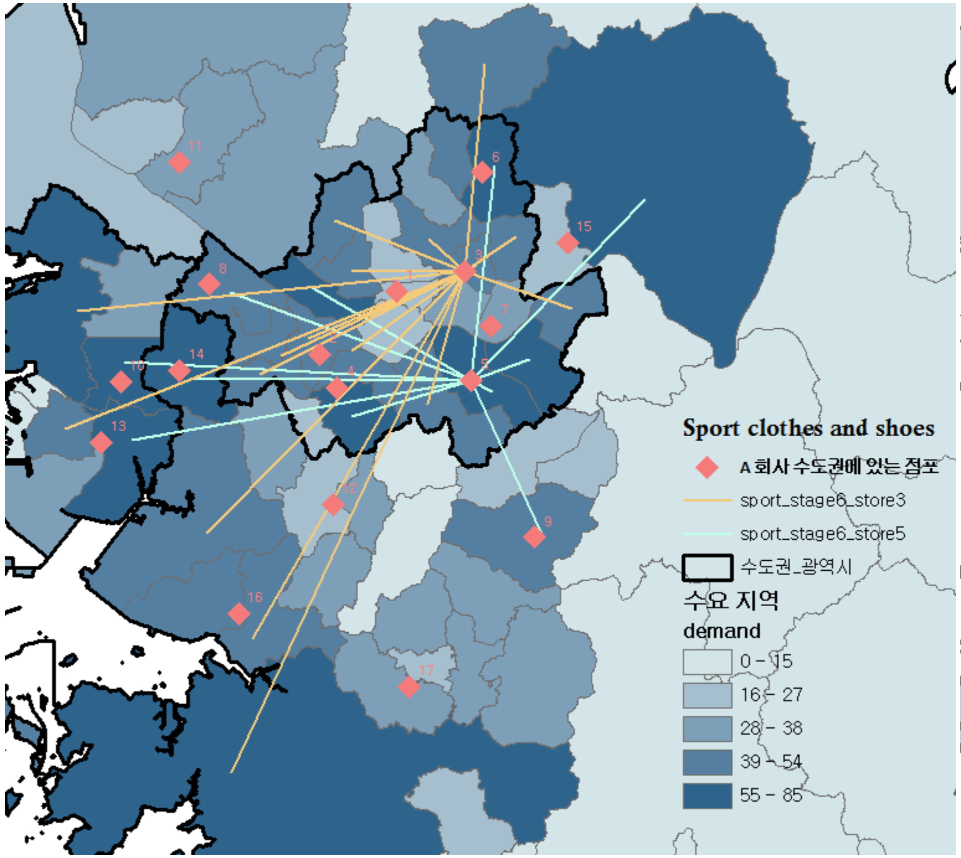
- Decentral distribution network
- Growth of costs is steady

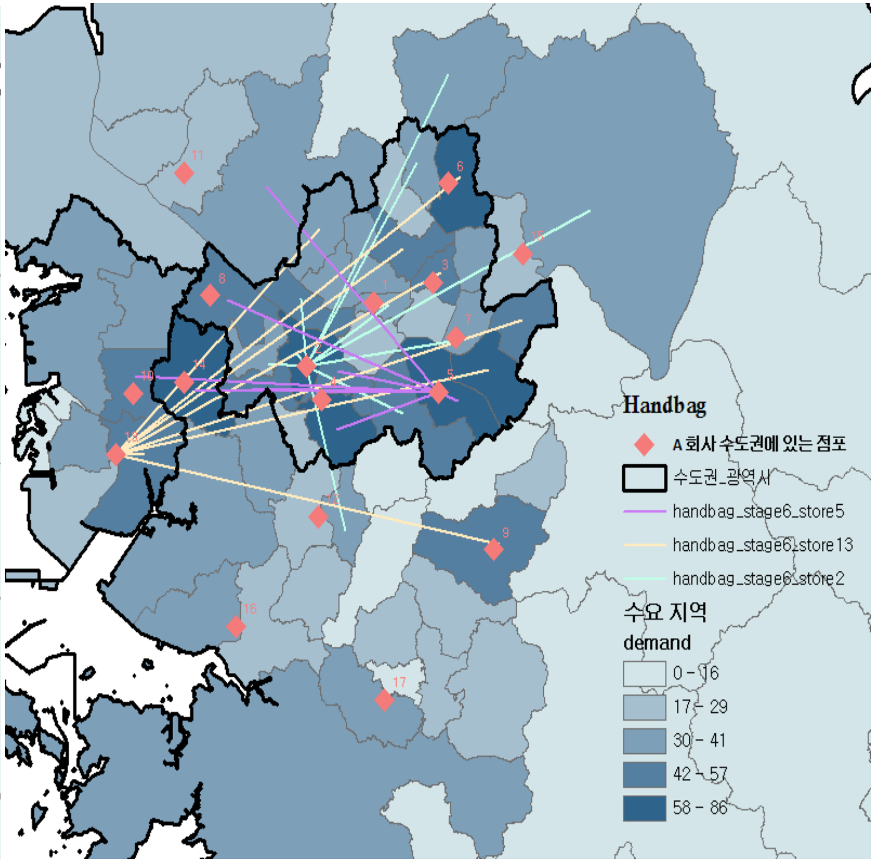
Analysis of multiple products

In-store standard deviation	'sport'	'handbag'
1	Store 7	Store 7
2	Store 2	Store 5
3	Store 3	Store 2
4	Store 4	Store 3
5	Store 10	Store 4
6	Store 5	Store 1

Total cost without fixed cost in 4 times

Store		Total	Without fixed cost	
'sport'	'handbag'	Unit 10000		
7+2	5+2+13	37814	15241	18517
7+2	7+3+13	37056	16297	19055
7+2	7+2+13	36934	16297	18934





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THANK YOU