A case study on improving delivery services for franchise stores using urban cross-dock centers considering traffic conditions

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Backgrounds: Growth of franchise business in Korea

- Despite the overall economic depression, franchise retail businesses have experienced steady growth over the past few years in Korea.
- Between 2013 and 2014, franchise businesses in Korea have grown 11% in terms of number of stores.

	2013		2014	
	Number of stores	Number of employees	Number of stores	Number of employees
Coffee shops	8,456	36,673	12,022	54,646
Bars	10,934	27,417	11,731	29,584
Convenient stores	25,039	94,735	26,280	98,863
Fried chickens	22,529	52,736	24,329	57,131
Fast foods	8,542	38,836	9,144	43,174
Others	19,471	55,340	21,662	64,471

Source: Korea Statistics

Challenges of satisfying delivery service needs for franchise retail businesses

- Widely spread distribution of stores over large metropolitan areas
- Increasing needs for small and frequent delivery services
  - Due to limited storage space, most coffee shops cannot hold large inventories thus requiring frequent deliveries in small quantities typically 3~4 times a week.
- Delivery time requirements
  - Example: Stores located in Seoul and Gyounggi province requires their deliveries to be made by 10:00am and 12:00pm respectively.
- Efficient usage of delivery trucks
  - Increase delivery truck usages and load factor while satisfying all the customer’s needs
- Overcome traffic congestions during rush hours

Objectives

Problem statement

- This study is based on the actual case of logistics service provider serving franchise stores including coffee shops and family restaurants in the Seoul Metropolitan Area of Korea.

- The case company currently operates only one distribution center in Yong-in City to cover the entire Seoul Metropolitan Area, which caused problems like:
  - Many stores were not able to receive their orders on-time
  - There were problems of imbalances in delivery loads and driving times among delivery vehicles.
  - Current delivery truck routes are not efficient.

Objectives

- The main objective of this research is to suggest a systematic framework of redesigning a distribution network and vehicle routing plan in order to improve delivery services for franchise stores by using an urban cross-dock center while considering road traffic conditions.

Expected outcomes

Locating urban cross-dock center

- The case company was not able to provide on-time delivery service to all 450 franchise stores spread across the entire Seoul Metro Area with single distribution center
- With additional transfer facility located in high demand urban area, the case company is expected to respond to customer order more quickly without having to hold extra inventory

Redesign of delivery routes

- Determine delivery service areas for each facility
- Improve vehicle usage and load factors by minimizing number of delivery vehicles
- Minimize overall traveling distances while observing promised delivery time for each store
- Accomplish multiple delivery trips for certain vehicles by implement inter-depot delivery routes

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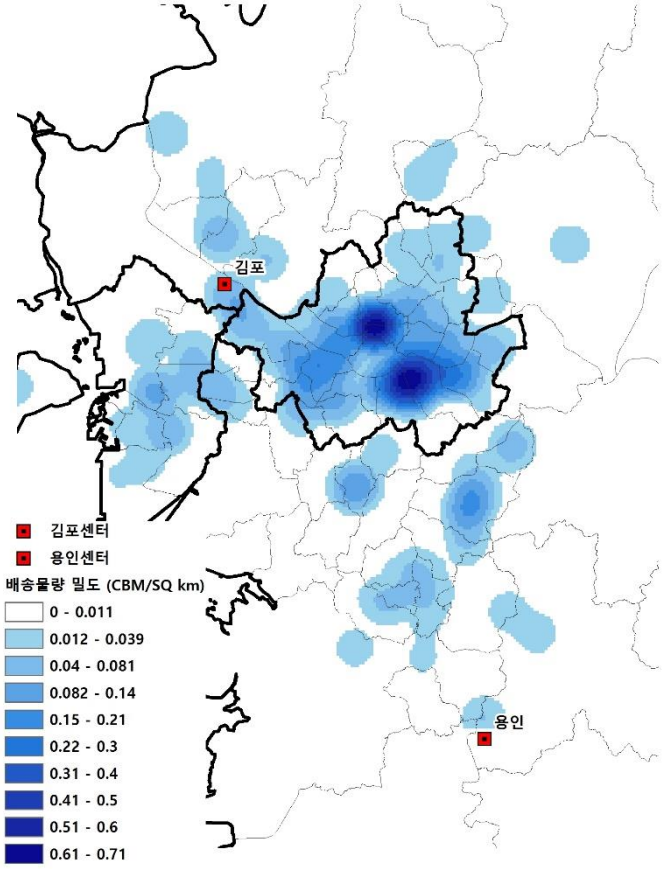
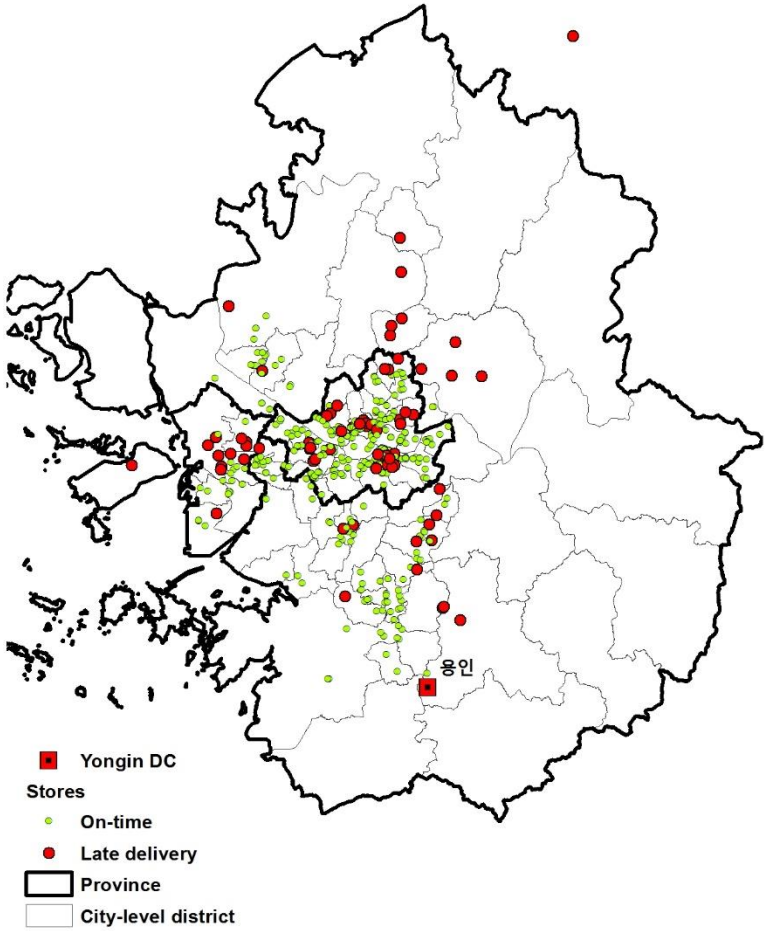
Delivery demand distribution

✓ Delivery demand distribution



- Delivery demand is mapped in terms of demand density (CBM/km^2)
- Demand is concentrated in the Jongro and Gangnam areas

✓ Stores suffering from late deliveries



- Stores located far away from the DC may suffer from delays due to long distance
- Incheon areas had most claims due to late deliveries

Problems in current delivery service

- Late deliveries in areas either with high demand or long distance from DC
- Imbalance in load factor and driving time among delivery vehicles

Vehicle ID	Truck size (ton)	Number of stores	Delivery quantity	Delivery volume (CBM)	Truck capacity (CBM)	Load factor (%)	Service area	Distance (km)	Start time	End time	Drive time
별도배송05	2.5	11	37	0.79	4.7	17%	군포, 동탄, 화성	140	2:00 AM	7:37 AM	5:37
별도배송06	2.5	10	42	0.93	4.7	20%	수원	75	2:00 AM	6:10 AM	4:10
본만제-01-6435	1	4	122	2.27	2.7	84%	잠실, 명동	96	2:00 AM	4:54 AM	2:54
용인-01-1290	2.5	15	227	2.68	4.7	57%	일산, 파주	167	3:10 AM	11:00 AM	7:50
용인-02-7247	2.5	21	259	2.86	4.7	61%	용산, 마포, 신촌	120	4:30 AM	12:00 PM	7:30
용인-03-4178	2.5	23	364	2.98	4.7	63%	동대문, 중계, 의정부, 철원	236	3:30 AM	2:30 PM	11:00
용인-04-2343	1.4	18	121	1.89	3	63%	부천, 부평	116	5:40 AM	10:40 AM	5:00
용인-05-2348	1	19	158	1.71	2.7	63%	양재, 강남, 역삼	84	5:40 AM	3:55 PM	10:15
용인-06-4585	1.4	12	162	1.75	3	58%	청담, 신사, 논현	78	5:00 AM	1:45 PM	8:45
용인-07-5587	1	13	174	1.83	2.7	68%	종로	113	4:40 AM	11:50 AM	7:10
용인-08-2212	1	20	295	4.53	2.7	168%	분당, 성남	124	5:00 AM	12:30 PM	7:30
용인-09-6373	2.5	24	235	4.2	4.7	89%	안양, 신림, 관악	120	3:00 AM	10:35 AM	7:35
용인-10-1125	2.5	11	387	6.46	4.7	137%	명동, 반포	81	4:20 AM	8:50 AM	4:30
용인-11-4170	2.5	16	418	4.37	4.7	93%	신촌, 여의도	94	3:30 AM	10:05 AM	6:35
용인-12-2077	2.5	15	386	4.59	4.7	98%	종로, 종구	83	2:30 AM	9:00 AM	6:30
용인-13-7306	1	10	168	1.63	2.7	60%	용인, 수원	67	2:00 AM	5:44 AM	3:44
용인-15-6957	2.5	21	448	7.23	4.7	154%	잠실, 남양주	181	3:40 AM	12:10 PM	8:30
용인-16-6545	1	20	375	3.48	2.7	129%	구로, 신도림, 목동	101	6:00 AM	11:53 AM	5:53
용인-17-5736	1	22	106	2.72	2.7	101%	동대문, 성북구, 중구	134	3:30 AM	11:01 AM	7:31
용인-19-2351	2.5	21	298	3.32	4.7	71%	일산, 강서	373	2:00 AM	2:26 PM	12:26
용인-20-1050	1	19	127	1.99	2.7	74%	강서, 광명	116	4:00 AM	10:00 AM	6:00
용인-21-6125	2.5	19	220	3.83	4.7	81%	인천 서구, 부평구, 계양구	137	5:00 AM	2:12 PM	9:12
용인-22-4015	1	15	144	2.64	2.7	98%	오산, 수원	152	5:40 AM	10:30 AM	4:50
용인-24-4571	3.5	16	576	7.68	6	128%	역삼, 강남	81	2:30 AM	7:30 AM	5:00
용인-26-2489	2.5	15	471	4.9	4.7	104%	강남, 압구정	83	4:00 AM	10:08 AM	6:08
용인-27-1087	2.5	26	229	2.4	4.7	51%	송파구, 강동구, 성동구	127	3:30 AM	9:30 AM	6:00
용인-30-9532	2.5	14	129	2.43	4.7	52%	안산, 시흥, 인천 송도	185	5:00 AM	11:10 AM	6:10
Total		450	6678	88.09	106.8	82%		3,464			183:15

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Research procedure

STEP 1 — **AS-IS Analysis**

- Analyze current demand distribution, truck dispatching plans, and delivery routes

STEP 2 — **Delivery Network redesign**

- Determine the number (*k*) of delivery routes based on truck capacities and delivery volumes
- Cluster store demands into k number of routes based on proximity, truck capacities, and demand volume using k-means algorithm

STEP 3 — **Simulate vehicle routing**

- Determine the location of cross-dock center
- Construct Daily Traffic Profile for the road network, and validate with the actual truck dispatch records
- Assign each route to facilities (DC and cross-dock center) based on several scenarios

STEP 4 — **Finalize delivery routing plan**

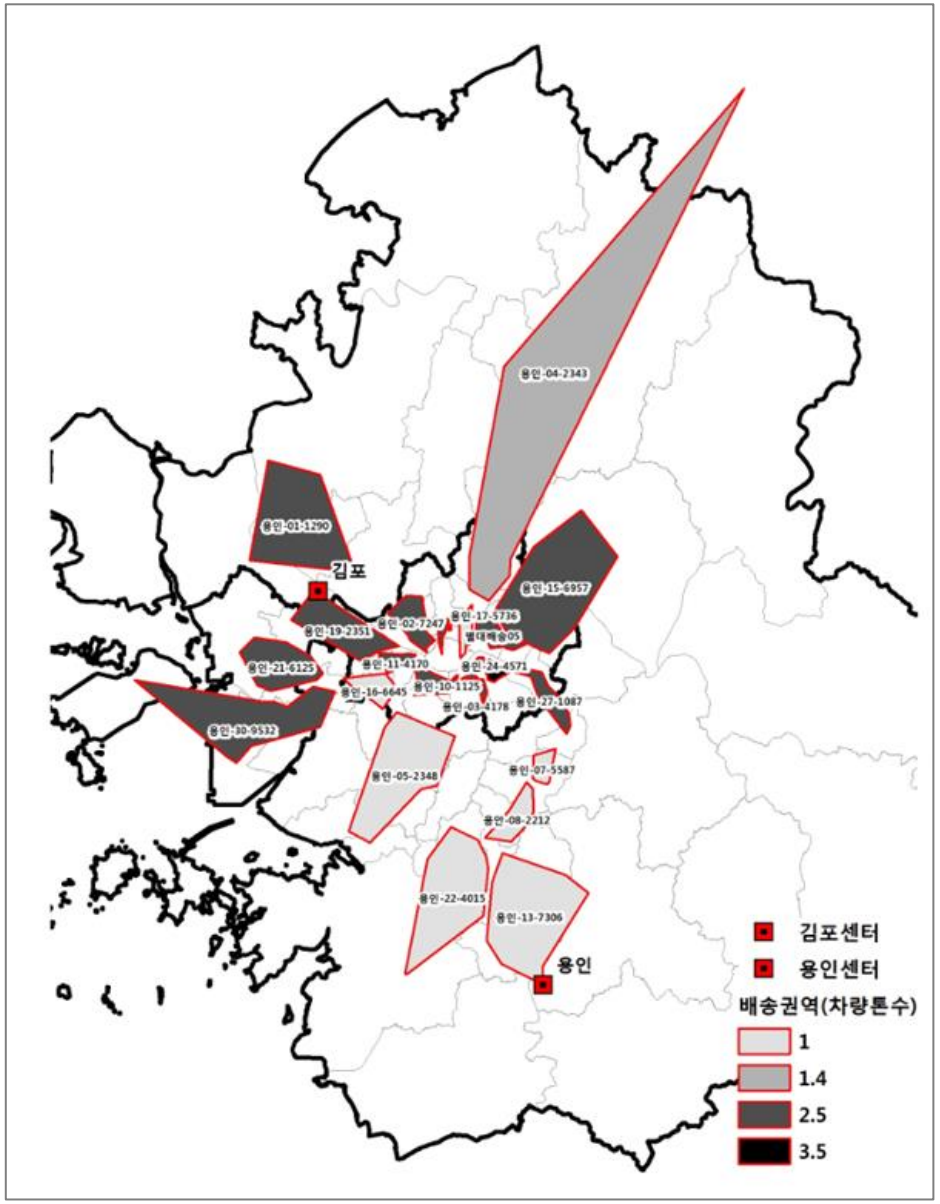
- Determine delivery routes for each truck considering traffic conditions by time-of-the-day (daily traffic profile)

Adjust the number of delivery routes by truck sizes

- Obtained the peak-day delivery data from the case company (as of July 2016).
- The case company was operating total 28 vehicles delivering total volume of 88.09 CBM to 459 stores across SMA resulting in average load factor of 80%.
- Currently 3.5 and 1.4 ton trucks are over utilized while 2.5 and 1 ton truck are under utilized.
- Even allowing extra 11% of current demand volume, it is concluded that the total number of trucks can be reduced to 24 increasing the average load factor to 87%.

Vehicle size (ton)	Vehicle capacity (CBM)	Before			After		
		Number	Total capacity (CBM)	Demand (CBM)	Number	Total capacity (CBM)	Demand (CBM)
1	2.7	10	27	22.8	6	16.2	14.75
1.4	3	2	6	3.64	2	6	5.76
2.5	4.7	15	70.5	53.97	15	70.5	62.18
3.5	6	1	6	7.68	1	6	5.4
Total		28	109.5	88.09	24	98.7	88.09

Cluster customer demands into the number of delivery routes



- K-means algorithm

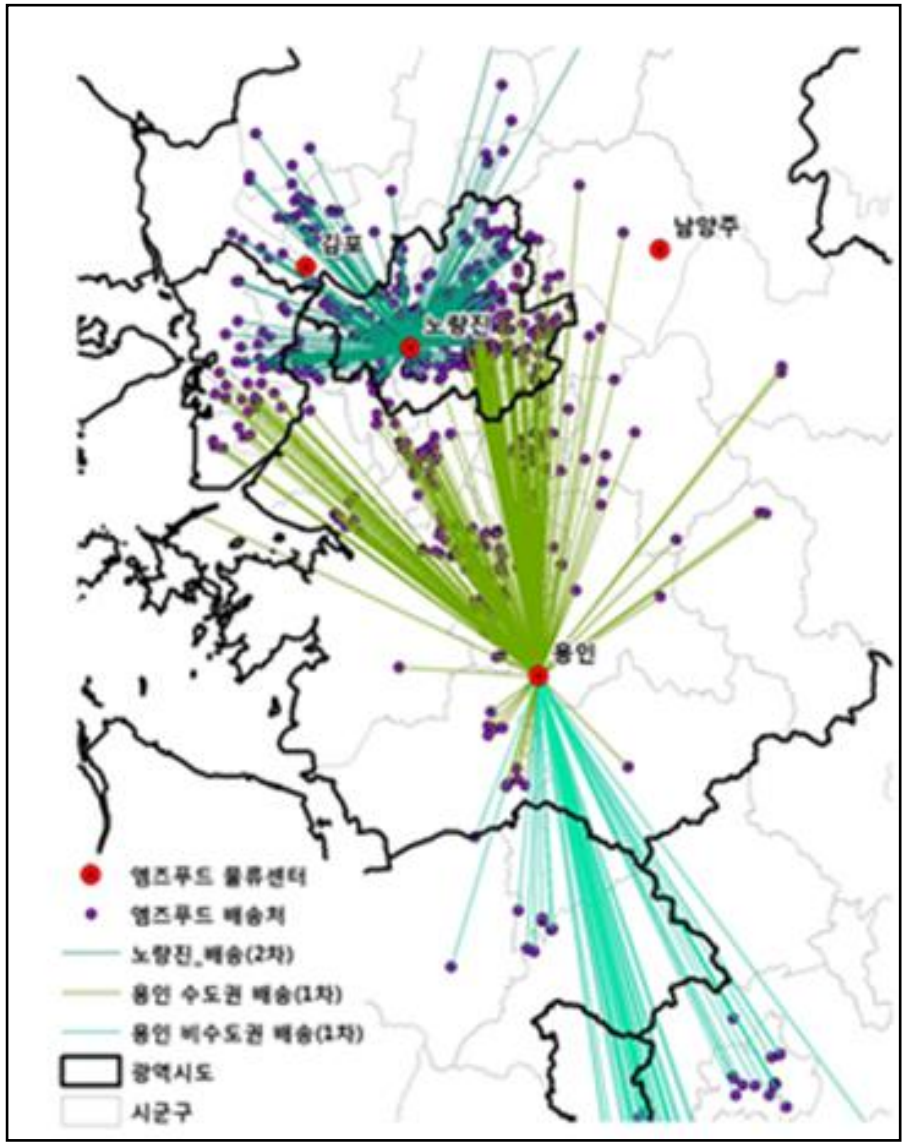
  Cluster 450 stores into 24 routes based on proximity using CrimeStat software

$$\arg\min_{\mathbf{S}} \sum_{i=1}^{k} \sum_{\mathbf{x}\in S_i} \|\mathbf{x} - \boldsymbol{\mu}_i\|^2$$

Distances within group are minimized while distance between group are maximized.

Determine cross-dock center location

✓ **Location-allocation analysis**



- Initially Gimop, Noryangjin, and Namyangju were considered as candidate for urban cross-dock center for the case company.

- Noryangjin was selected to be the best in terms of minimizing the total weighted distance from facilities to demand centers

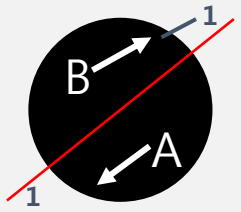
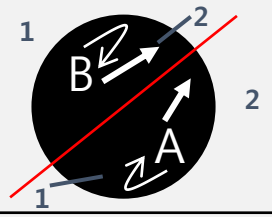
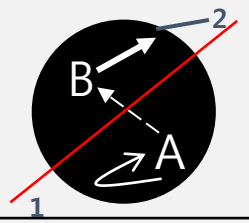
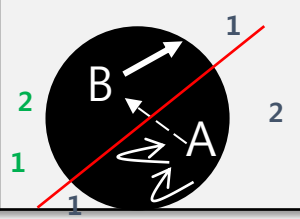
- Other practical conditions were considered
  1) Large-size truck access should be granted
  2) Consistent operation of the facility should be guaranteed for the near future

  → Noryangjin deed not meet these conditions

- Reconsider between Gimpo and Namyangju

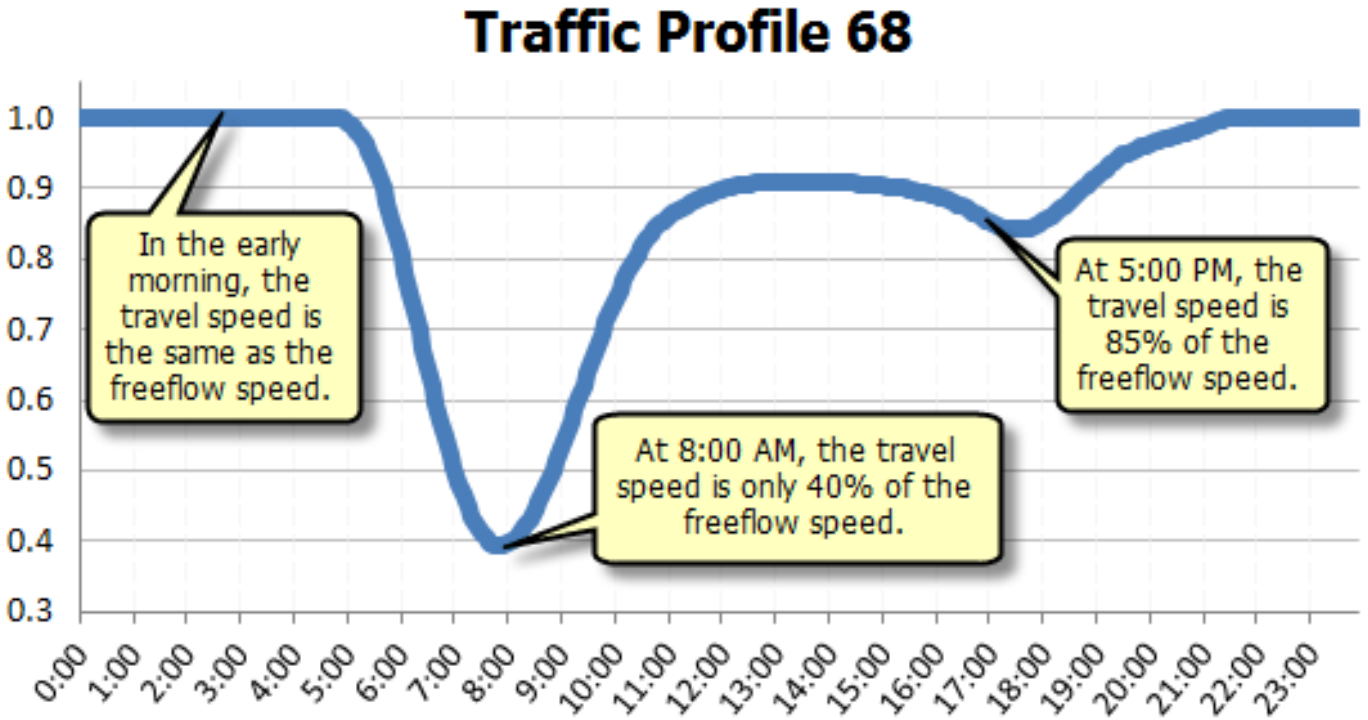
- <u>Gimpo was finalized as the cross-dock center location</u>
  1) Good logistics infrastructure (logistics complex developed)
  2) Gimpo can improve delivery service quality to the western part of SMA including Incheon

Assigning routes to facilities

Scenario	Description (A : DC, B : Cross-dock center)	
Scenario 1 (Single cycle only)		Perform single cycle delivery from A and B independently
Scenario 2 (Double cycle only)		Perform double cycle delivery from A and B independently
Scenario 3 (Inter-depot double cycle delivery)		Perform initial delivery starting from A, move to B and perform second delivery
Scenario 4 (Combine scenarios 1+2+3)		Single or double cycle delivery from either A or B + Inter-depot delivery from A to B

Daily traffic profile by time

- Traffic profiles by time-of-the-day are constructed based on existing empirical researches(Kim and Lee, 2014) and configured to be used with ArcGIS Network Analyst extension.
- Travel time = Free flow speed * Speed factor
- Daily traffic profiles are adjusted by validating with the actual truck dispatching records provided by the case company (as of July 2015).
- Daily traffic profiles enable us to obtain more realistic driving time reflecting the actual road traffic conditions by time-of-the-day,

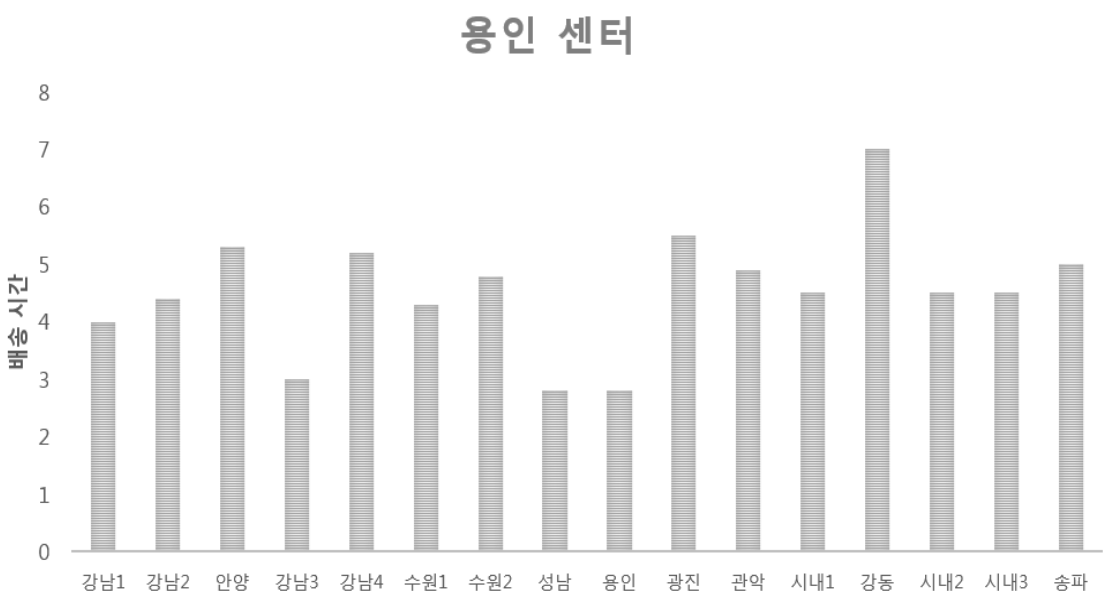


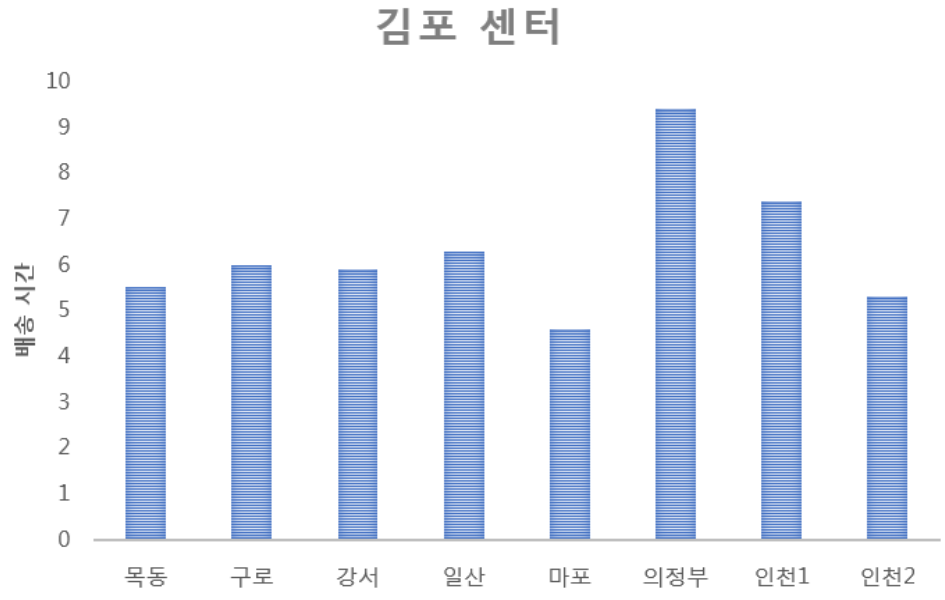
Daily traffic profile example

Source: ESRI(2015) ArcGIS User Manual

Expected results

Scenario 1 : Single cycle delivery from Yongin DC and Gimpo X-dock center

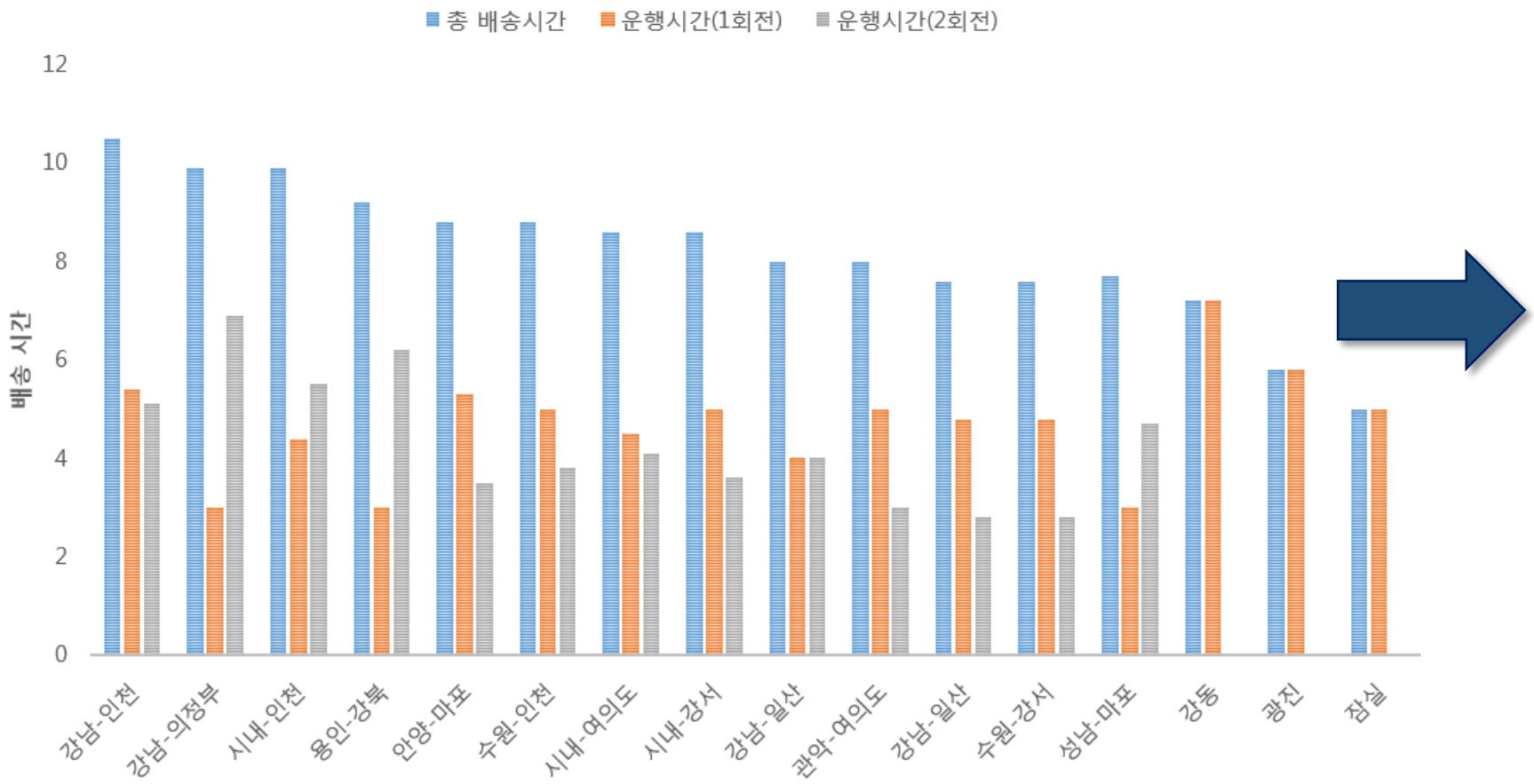




- **Number of vehicles : 24**
- **100% On-time delivery**
- **Low vehicle utilization**

Expected results

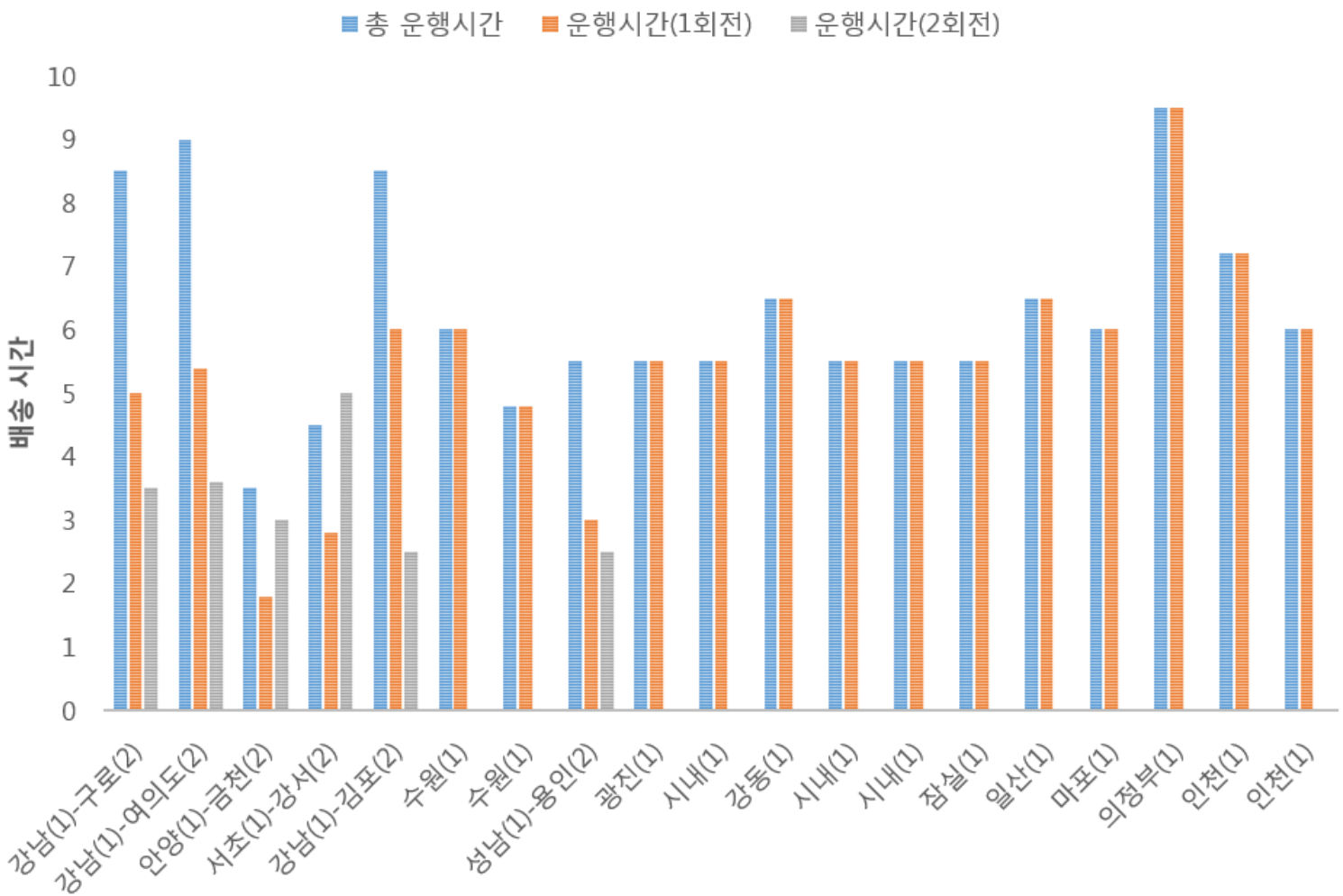
Scenario 3 : 1st Delivery from Yongin DC, move to Gimpo and perform 2nd delivery



- Number of vehicles : 16
- Late delivery occurred

Expected results

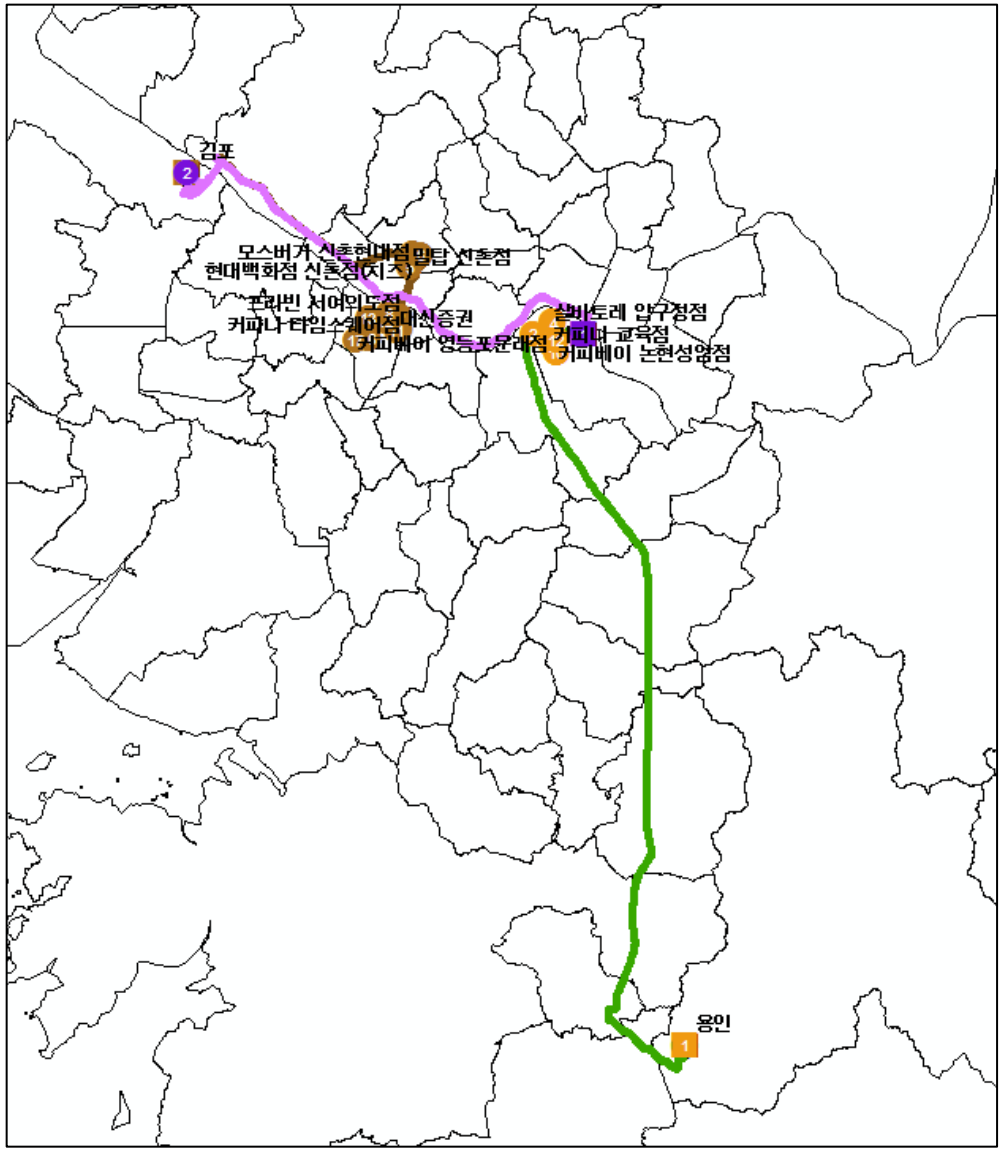
Scenario 4 : Scenario 1+2+3



- **Number of trucks: 20**
- **100% on-time delivery accomplished**
- **Load factor balanced: 70~80%**

Example of inter-depot delivery route

- Start from Yongin DC at 1:00AM when there is little traffic on the roads;
- Perform 1st round delivery in high demand Gangnam area in the early morning;
- Finish 1st round delivery by 5:00 AM;
- Move to Gimpo X-dock and reload at 6:30 AM;
- Perform 2nd round delivery near Gimpo X-dock such as Gangseo area in Seoul.
- Finish 2nd round delivery by 10:00 AM



Conclusions

	Number of vehicles	Vehicle usage rate	On-time delivery rate
Scenario 1	24	Low	100%
Scenario 2	16	High	70%
Scenario 3	20	High	100%

- Both scenarios 1 and 3 can accomplish 100% on-time delivery rate.
- Load factors are higher in Scenarios 2 and 3.
- Scenario 2 requires minimum number of vehicles, however late delivery can happen.

Adopt Scenario 3

Implications

- The needs for cross-dock centers in the high demand urban areas are increasing due to the needs of small-size frequent delivery services from the fast growing franchise retail businesses.
- Urban cross-dock centers can improve customer response time without holding extra inventory.
- Stores need to be appropriately clustered and assigned to each route so that driving time (or distance) and delivery loads are balanced for each vehicle.
- Multiple cycle delivery or inter-depot routes can increase the delivery truck utilization.

THANK YOU