한국빅데이터학회지
제4권 제2호, 2019, pp. 159-173

Designing the Optimal Urban Distribution Network using GIS : Case of Milk Industry in Ulaanbaatar Mongolia

GIS를 이용한 최적 도심 유통 네트워크 설계 : 몽골 울란바타르 내 우유 산업 사례

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Abstract

Abstract: Last-Mile delivery optimization plays a key role in the urban supply chain operation, which is the most expensive and time-consuming and most complicated part of the whole delivery process. The urban consolidation center (UCC) is regarded as a significant asset for supporting customer demand in the last-mile delivery service. It is the key benefit of UCC to improve the load balance of vehicles and to reduce the total traveling distance by finding the better route with the well-organized multi-leg vehicle journey in the urban area. This paper presents the model using multiple scenario analysis integrated with mathematical optimization techniques using Geographic Information System (GIS). The model aims to find the best solution for the distribution network consisted of DC and UCC, which is applied to the case of Ulaanbaatar Mongolia. The proposed methodology integrates two sub-models, location-allocation model and vehicle routing problem. The multiple scenarios devised by selecting locations of UCC are compared considering the general performance and delivery patterns together. It has been adopted to make better decisions the quantitative metrics such as the economic value of capital cost, operating cost, and balance of using available resources. The result of this research may help the manager or public authorities who should design the distribution network for the last mile delivery service optimization using UCC within the urban area.

■ Keywords: GIS, Urban Distribution Network, Last Mile Delivery, UCC

요 약

말단배송최적화는 도심내 공급사슬의 운영의 핵심적인 역할을 수행하고 있으며, 전체 배송 프로세스에서 가장 복잡하고 많은 비용을 지불해야만 한다. 도심복합물류센터 (Urban Consolidation Center: UCC)는 최근 말단배송 서비스를 운영하고 고객의 수요를 만족시키기 위한 핵심적인 자산으로 인식되고 있다. UCC를 활용할 경우 도심 내 다양한 요인을 고려하여 최적의 배송 과정을 설계함으로써 배송에 소요되는 시간과 이동거리를 최소화할 수 있다는 장점이 존재한다. 본 연구에서는 지리정보시스템 (GIS)를 활용하여 다양한 수리모형이 통합된 시나리오 분석을 활용하기 위한 기법을 제안한다. 특히, 본 연구는 몽골의 수도 울란바타르를 사례로 실제 도심 내 최적 배송네트워크를 설계하는 것을 목표로하고 있다. 이를 위해 위치배분문제와 차량경로문제를 결합하는 기법을 제안하였다. UCC의 위치와 개수를 기반으로 다양한 시나리오를 설계하였으며, 기본적인 총배송거리, 배송시간, UCC의 수 및 필요 차량의 수를 기준으로 시나리오를 평가하였다. 또한, UCC의 건설과 운영에 필요한 전체 비용 관점에서 최적의 시나리오를 비교 선정하였다. 본 연구의 결과는 도심 내 말단 배송을 위한 유통 네트워크를 설계해야 하는 관리자 혹은 정부 기관의 담당자들이 합리적인 의사결정을 내리기 위한 객관적인 근거 자료로 활용될 수 있을 것이다.

■ 중심어: 지리정보시스템, 도심 유통 네트워크, 말단 배송, 도심복합물류센터

2019년 11월 30일 접수; 2019년 12월 10일 수정본 접수; 2019년 12월 31일 게재 확정.

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Ⅰ. Introduction

Although the last-mile delivery plays a key role in achieving the urban supply chain performance, it is most expensive, time-consuming and most complicated part of the whole delivery process. Especially, the last-mile delivery takes the most dominant portion (53%) of the whole transportation cost[1]. Usually, the last-mile delivery takes the first step to pick up the freight from suppliers to resellers or drop off from resellers to final customers. It requires a very large number of small carriers for the frequent deliveries with very small shipment. It makes the delivery routes of some carriers overlapped. Therefore, the last-mile delivery is regarded as the major source of traffic congestion in urban areas.[2]

Urban consolidation center (UCC) is regarded as a significant asset for supporting customer demand in the last-mile delivery service. The UCC is a new concept of logistics facility that receives inbound transport and serves as the depot for last-mile deliveries, and also the freight can be stocked and appropriately bundled in order to be dispatched to the various destinations[3]. The key benefit of UCC is an improving the load balance of vehicles by reducing the total traveling distance or finding the better route with the well-organized multi-leg vehicle journey in urban areas.[4].

In Mongolia, due to the unprecedented rapid urbanization, the demand for fresh and perishable foods continues to increase, and a challenging more comprehensive transportation network for fresh food delivery in urban areas. For example, Mongolia has 66 million heads of livestock, total annual milk production volume is approximately 928,000 tons. Nevertheless, the milk production and distribution industry of Mongolia cannot supply the full domestic consumption in the current market. The main reason of problem is the inefficient, logistic distribution capacity. Because, the most of supply chains consists of the manufacturing plants, independent warehouses, and retailing shops are not well designed and located in the central area of the city. At first, all finished goods and raw materials are transported into the city. Then after finishing the processes such as refining, packaging the final products are again distributed to the retailing stores using their own fleets across the various locations which are widely distributed over the urban area. This complicated distribution network makes additional movement of freight and worse the social problems like traffic congestion, noise, and emissions.[5]

Especially, the most of commodities are transported across over the urban area with the various size of trucks, which are operated by importers and manufacturers. Although the capacity of trucks varies between 2.5 tons and 5.0 tons in the urban area like Ulaanbaatar. According to the Traffic Police Department, there are more than 67,999 delivery vehicles including trucks, vans and private cars which are operated in Ulaanbaatar. Specifically, about 12,000 vehicles operate around the city center and they stop frequently. Usually, the logistic and transport cost contributes for about 30 percent of prices of goods[5]. Not only the various trucks for delivery but also vehicles for passengers passing through the urban area is regarded as the most important source of the traffic congestion in Ulaanbaatar. It causes the operating cost and additional social problems like accidents and pollution. Therefore, it is required the strategic plans for building the more sustainable and efficient urban logistics network.

Urban Consolidation Center (UCC) is emerging concept of logistics facility for achieving the essential role of saving distribution cost and minimizing traffic congestion along the freight delivery within the urban areas. Especially, the location of UCC is one of the most important factors which have a great impact on logistics performance. Because the location of UCC is linked with several factors such as socio-economy, logistics business itself, environment, safety and traffic, all of these factors should be considered at the same time in order to select the optimal location. Also, UCC has the different aspects which have negative impact on the performance such as high infrastructure cost, limited available space, congestion problem, limited vehicle access time windows while comparing with other logistics facilities. In addition, it is regarded as the most important issue to build the sustainable urban logistics network without giving up the service level and performance.

However, the most of previous research have focused on designing optimal network structure with minimum number and optimal locations of logistics facilities considering only demand or route for delivery from the distribution centers. Therefore, in this study, it has been presented a framework to design the supply chain network, which can minimize the total cost for building UCC and operating the distribution with the practical conditions for delivery. To find the optimal distributing network, it has been integrated the Locating-routing problem (LRP) with Location-allocation problem (LAP) and vehicle routing problem (VRP).

The main contribution of this research can be summarized as follows: At first, we evaluate the performance of the current distribution network for milk and dairy products without UCC. We compared the performance of several scenarios with multiple UCC and it is possible to make better decision to design the distribution network using UCC. In details, we presented the various quantitative performance indicators to compare ten different scenarios such as the total traveling time, total traveling distance, number of required trucks, minimum number of UCC, and fairness among drivers based on the practical demand and traveling routes. The result of comparing analysis may help the top manager or public authorities who should design the distribution network in order to support the growing demand for milk and dairy products.

The rest of this paper is structured as follows. In Section 2 literature review of distribution of network of UCC in urban area. In Section 3, the background and details of proposed approach are described. Scenario analysis and sensitivity analysis is presented and discussed in Section 4. Finally, we will conclude our research with contributions, limitation and future research in Section 5.

Ⅱ. Literature review

The optimal location selection of the Urban Consolidation Center (UCC) is emerging as an essential role for saving distribution cost and minimizing traffic congestion arising from freight Last-Mile delivery within the urban areas. UCCs implementation schemes in a changed distribution pattern, especially design of distribution structure was the most common suggestion among the studies[6][7][8]. The studies described the changes in the number of vehicle trips as changed in the number of vehicle kilometers and changes in the number of vehicles. Most of studies highlighted the importance of considering selection of location. The geographical location of UCCs has great impacts on the performance of last-mile delivery service. There exists tremendous previous research which suggested various methodologies, optimization models for selecting the optimal location. Furthermore, different methods were applied. As described above, Locating Routing Problem (LRP) integrating network design UCC literature has a focused on three elements: 1) changing network design in UCC 2) GIS based network analysis tools solved by the VRP 3) research approach (Covering problem).

It is possible to find the research which has been analyzed by changing network design of UCC[9], which integrated the optimal location of UCC with capacity and budget and fleet choice-routing with time, capacity, and budget limitation using meta-heuristic technique based on Genetic algorithm (GA). Also, the searching algorithm has been applied to optimize the location of UCC; to de-

〈Table 1〉 List of Previous research and problems

1. Transportation network design for Urban Consolidation Center				
References	Research objective	Solution algorithm	Modeling methodology	Type of facilities
Simoni et al., 2018	This study problem is to minimize the total cost of implementing UCCs and minimize emissions.	Genetic algorithm (GA)	LAP, VRP, fleet size	Private UCC
Jacyna, 2013	The identified the transshipment problem, which minimize the total distance and route assign.	Nonlinear programming	LAP, VRP	Public and Private CCC
Roca-Riu and Estrada, 2012	Cost minimization, which present model to estimation distribution cost in urban area, with and without consolidation center.	Nonlinear programming	VRP	Public and Private UCC
Taniguchi et al., 1999	The model aims to mathematical model developed for minimized transportation cost and facility cost of public logistics terminals.	GA	LAP, VRP	Public DC
van Heeswijk et al., 2019	Main finding this study, calculating differences between centralize or decentralize in good delivering for UCC solve to minimizing cost.	Heuristic algorithm	VRP	Private UCC
2. GIS based network analysis tools solved by the vehicle routing problems.				
References	Research objective	Solution algorithm	Modeling methodology	Type of facilities
Bosona et al., 2013	This study aim is evaluating performance of an integrated food distribution network (IFDN) in domestic fresh food supply chain.	GIS	LAP, VRP	Public DC
Keenan, 2008	This study identified the GIS VPR model supporting more useful for solving optimization of network distribution problem.	GIS	VRP	-
Janjevic et al., 2016	Cost minimization, which present model to estimation distribution cost in urban area, with and without consolidation center.	GIS	LAP, VRP	Public city DC
Juthathip, 2019	The objective is finding the best solution has been done for all candidate locations of DC and minimizing transportation cost.	GIS	LAP, VRP	Public DC

3. Locating covering problem				
References	Applications	Solution algorithm	Modeling methodology	Type of facilities
Murray et al., 2019	a) Minimum location of Fire station in Northwest Boston, which covering 124 km2 and 511 demand point b) Supplemental nutrition program in Santa Barbara county, which covering 7080 km2 and 5,389 census blocks demand point c) Beverage container recycling center in San Jose, which covering 466 km2 and 59 demand point	GIS, Trans CAD	LSCP, MCLP.	Public and Private
Lee et al., 2019	Unmanned parcel lockers in Incheon metropolitan city in Korea. Case study area 200-300 m. The demand point is 222 household customers	GIS, CPLEX,	LSCP, PMP,	Public
Xue et al., 2017	Urban mining recycling facilities in China. 200km demand point is population and GDP is covering	GIS	AHP, MCLP,	Public
Straitiff and Cromley, 2010	Emergency warning danger signal. Covering 63.3 km^2 and demand point 1164.	GIS	LSCP	Public

termine different type of fleet vehicles and considering optimal delivery routes from UCCs to their assigned customer. The objective of the problem is to minimize the total cost of implementing UCC and minimizing emissions based on scenarios of policies.

In summary, a few previous studies investigated the solution of the LRP. In addition, the most of previous research tried to find the optimal design of network considering only some of indicators such as the number of facilities, travelling distance, travelling time, and number of trucks. Therefore, in this study, it has been assumed that the fundamental problem for cost minimization as the economic dimensions of sustainability perspective and designing the distribution network as previous literature. However, we integrated two main approaches, LAP and VRP. Also, we have applied the scenario analysis that can compare the different approaches such as closest facility, minimize the number of UCCs, and maximize coverage and compare the performance with several difference metrics to evaluate the performance.

Ⅲ. Methodology

3.1 Background of the proposed framework

The two main sub-models, the Location-Allocation Problem (LAP) and Vehicle Routing Problem (VRP), have been integrated into the research framework as Locating Routing Problem (LRP). The present framework can be divided into two main parts, location phase and routing phase. Firstly, the location-allocation model is finding the best location of UCC and demand allocation. Second, the routes of vehicles are then generated to visit all demanding points from UCC. The change to distribution design with required truck while, minimizing the total traveling distance while, delivering milk and dairy products from production plant warehouse to optimal number of locating UCC to retailers. The purpose of LAP is to minimize to overall distance between demand points and facilities, maximize the number of demand point covered within a certain distance of facilities, maximize an apportioned amount of demand, or maximize the amount of demand captured in an environ ment of friendly and competing facilities.[10][1]

In general, the Maximum Covering Location Problem (MCLP) discussed the location of a fixed number of facilities which have high potential of being insufficient to cover all demand within the standards, which the demand covered by the service is maximized, when budget and resources are limited, the fixed number of facilities can act as a proxy in this case[10]. Vehicle routing problem (VRP) involves minimizing traveling costs, minimum traveling distance, and set of vehicles to distribute all the product from depot node to other demand nodes[11]. Each enterprise needs to determine which orders should be serviced by each route and what sequence the order be visited[12]. The main objective is to determine the optimal route in a distribution system in which vehicles are allocated to serve a set of customers.

3.2 Current network structure and basic assumptions

Suu Joint Stock Company (JSC) began production of milk in 1958 and now it is ISO 9001:2008 ISO quality certified. At the end of 2017, the company had an extension of equipment 570BCP a pure pack packaging machine from Nimco, U.S. producer of equipment, which enabled packaging capacity to increase up to 200%. Company production capacity is approximately the daily capacity of processing 200 tons of milk and manufactures about 70 types of products as of now.[13]. The biggest milk and dairy product manufacturer in Ulaanbaatar primarily purchased its raw milk from Tuv, Selenge, Khentii and Zuunkharaa provinces located nearby Ulaanbaatar. Milk collected from farms and herders is transported to the facility for processing of pasteurization and manufacturing of the final products. These final products are packed and stored in the independent warehouses where to be distributed to retailers all over the city by its own fleet.

The main problem of the distribution network of this company is the inefficient last-mile delivery. Especially, the increased cost of transportation caused by the excessive number of small deliveries to the widely distributed customers with small volume of demand. For instance, the company delivers its products to an average of 2,930 retailers monthly. The average quantity of customer order is 900 or more a day, which means that 10,9790 final products should be distributed to more than 800 demanding points. It has been calculated the degree of centralized or decentralized distribution [14]. From the result, it can be found that the single supplier delivers average 4.05 times a week from the DC to each demanding point. Also, each demanding point get the products from 2-4 suppliers, and in total 11.65 times deliveries per week.

First of all, we have selected 757 retailers based on patterns and frequency of order within the most congested commercialized area in Ulaanbaatar. Currently, about 113 vehicles visited to the M supermarket and 105 vehicles visited to the Blue Mon building, with the peak arrival hour is 12-1pm for M supermarket and 11-12pm for Blue Mon building. The vehicle service time is dependent to the volume of demand and average 6-25 minutes for loading and unloading operations. Because between 11am and 2pm is the peak time

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[1] ArcGIS Desktop Website (http://desktop.arcgis.com/en/arcmap/latest/extensions/main/about-arcgis-for-desktop-extensions.htm).

for delivery, it has been assumed that the maximum operating duration is 3 hours (180 minutes). Currently, the average capacity of trucks is between 3.5 tons and 5.0 tons. In this research we have assumed the capacity of trucks is 2.5 tons considering the decreased volume when using UCC in the urban area.

3.3 Assumptions for candidate location of UCC and demanding points

The location of candidate UCC are depicted in Figure 6, which are selected based on the following criteria. First, it should be located nearby the city center and is close to end-customer. The local authorities, in their strategic plan for Ulaanbaatar City Master plan (2020-2030) have established goal of a more suitable decentralized city from a mono-center city to divided nine sub-centers with nine distribution centers. We selected as these nine specific distribution centers as the candidate of UCC for building scenarios. Second, it should be well-connected the main road network like highways. The previous research[8, 15, 16] highlight the importance of the location, road network condition for the success of UCC's operation. We have identified four more candidate locations of UCC nearby the main intersection of the road network in Ulaanbaatar. Finally, we have identified the 13 candidate locations. For the demanding points, we found the practical locations of delivery points such as supermarket, grocery store, small shop and convenient stores. From the Open Street map[2], it was possible to secure the Geocodes of 756 retail locations.

In general, each UCC has the limited capacity, which is depend on the available size of candidates. The available space and maximum capacity of each candidate UCC are described in Table 2.

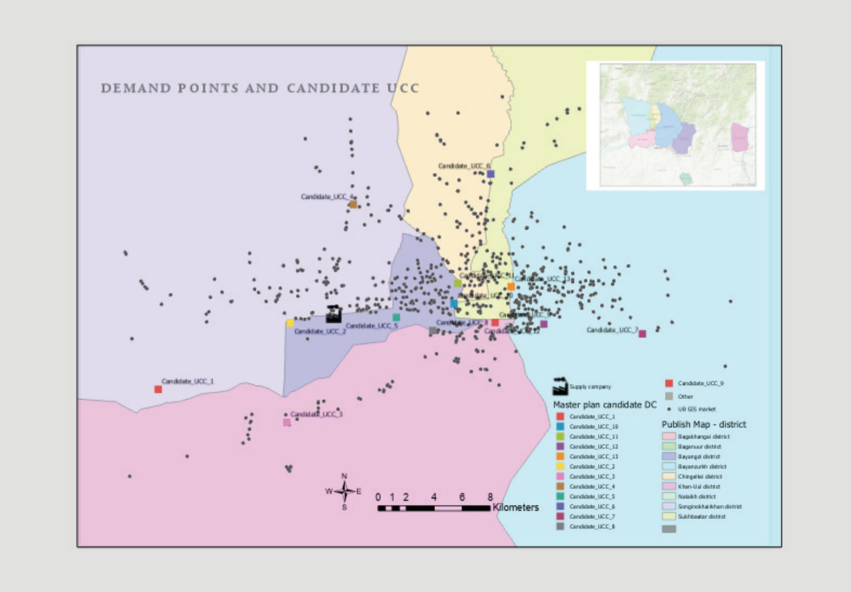

Figure 1. Locations of candidates UCC and demanding points

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[2] https://www.openstreetmap.org/#map=14/47.9110/106.8868

〈Table 2〉 The maximum level of capacity

Potential UCC	Maximum storage capacity (ton)	Total floor area (sq. m)	Overall site area (sq. m)
Supply company	200.0	500.0	2000
Candidate_UCC_1	-	-	-
Candidate_UCC_2	601.24	250.52	1002.07
Candidate_UCC_3	145.04	60.43	241.73
Candidate_UCC_4	183.47	76.45	305.78
Candidate_UCC_5	1189.47	495.61	1982.45
Candidate_UCC_6	392.38	163.49	653.97
Candidate_UCC_7	52.07	21.70	86.78
Candidate_UCC_8	295.76	123.23	492.93
Candidate_UCC_9	768.26	320.11	1280.43
Candidate_UCC_10	7.68	3.20	12.80
Candidate_UCC_11	426.02	177.51	710.03
Candidate_UCC_12	317.7	132.38	529.50
Candidate_UCC_13	1921.38	800.58	3202.30

3.4 Assumption for initial investment cost and operation cost

In this research, it has been focused on finding the minimum number of optimal locations of facilities while supporting the demand from the delivery points and minimizing the total cost which consists with the initial investment and operating cost. It has been reported that the logistic and transport cost contributes for about 30 percent of the price of goods[4]. In order to calculate the total cost, we have assumed the unit cost for building UCC and operating distribution network as depicted in Figure 2.

Regarding to operating cost of UCC service, several unit cost can be found from[14, 16, 17, 18] as described in Table 2. From the sources, it has been adopted the unit cost from the Mongolian parcel company, However, we will used minimum cost rate for the price of UCC service from $0.92 to $2.77 per parcel and from $1.69 per 10kg.

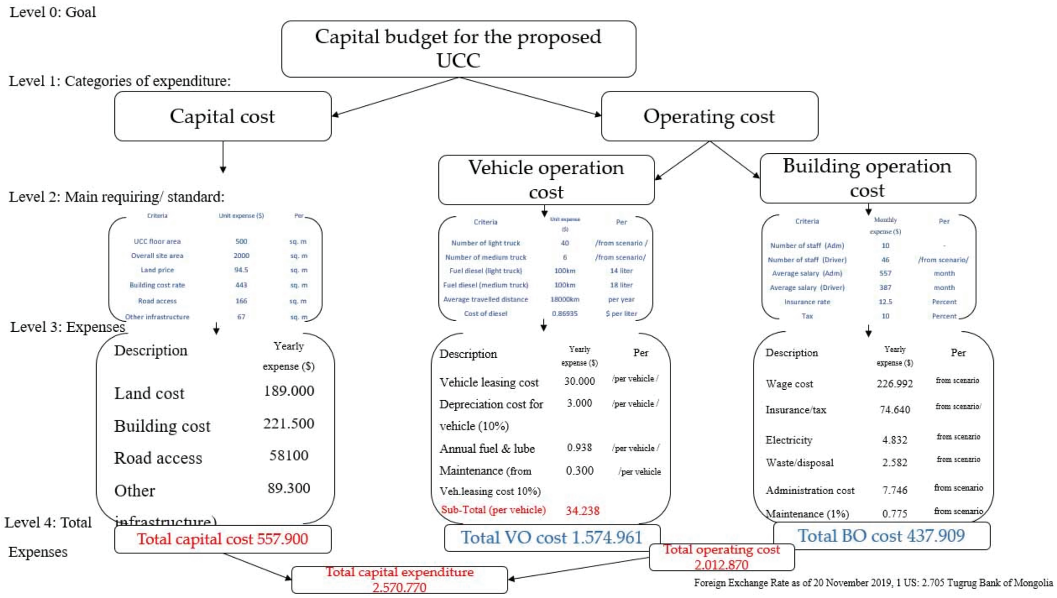
According to[14], it has been assumed the variable cost for UCC, which include transportation cost, handling cost and cost of value-added service.

3.5 Scenarios building

The objective of this research was to identify the optimal number and location of UCC to support the demand of retailers. In Table 4, it has been described and outlined the ten possible scenarios. Scenario 1 illustrated current situation of Last-Mile delivery network in Suu JSCompany. We also suggest three different approaches to choose the location of UCC. At first, the closest facility analysis was applied to choose UCC out of thirteen candidates in scenario 2. Secondly, in scenario 3, we will identify the minimum number of UCC required to cover all demand, which can be described by ‘n’. Finally, we applied the maximizing coverage that all demand points can be reached within a specified response, which the number of facilities should be determined at first. From the scenario 3 with n UCC, it is possible to build 10 more scenarios by increasing the number of UCC.

3.6 Set up for Scenario analysis

For all scenarios, the optimal distribution network



〈Figure 2〉 Capital budgeting for proposed UCC

〈Table 2〉 Price of UCC service

Sources	Per Parcel	Per Pallet	Case Study
(Scott Wilson, 2010)	-	100 kg/$5.43	Monaco UCC
(Duin et al., 2016)	$2.77-5.5	$11.08-22.17	Brusselss UCC
(Lewis et.al., 2007)	$3.21-7.87	$7.87-15.85	London UCC
(Janjevic et al., 2016; Ltd, 2010)	$2.77-5.5	$11.08-22.17	Brusselss UCC
(Kgb tegbe Mongolia 2019)	$0.92-2.77	10kg /$1.69	Mongolia parcel company

*Foreign Exchange Rate as of 20 November 2019, USD: 2.705 Tugrug, Bank of Mongolia

〈Table 3〉 Cost of UCC

Component	Value	Description
Costs transport	$0.8/km+$23.3/hr	Depend on route
Costs handling	$7.8-22.17/m^3	Depending on volume ratio, exclude transport
Cost of value-added service	56-95% of SC activities costs	Depending on volume ratio

*Foreign Exchange Rate as of 20 November 2019, USD: 2.705 Tugrug, Bank of Mongolia

〈Table 4〉 Summary of building scenario

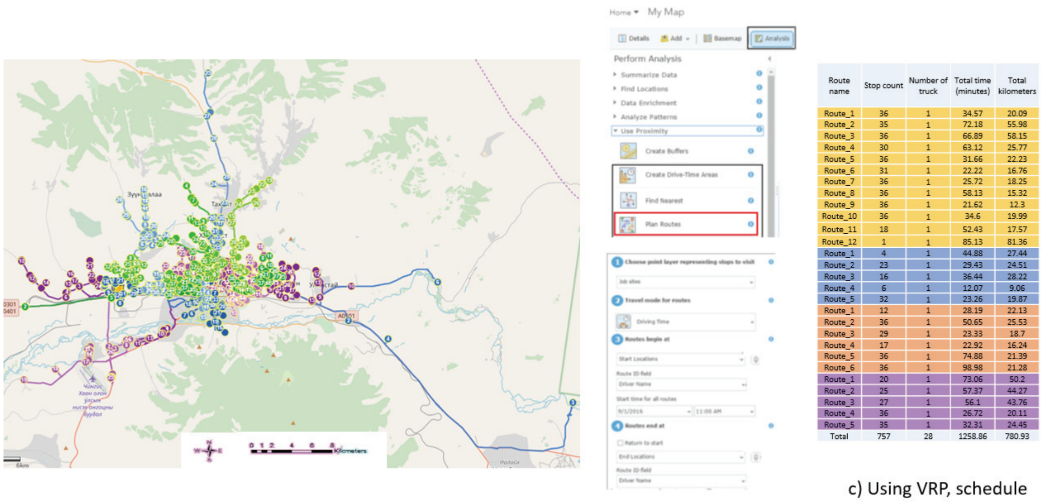
Scenario	Location Analysis Method	Lead time (min)	Number of DC
Scenario 1	Without UCC	-	1
Scenario 2	Closest facility	-	13
Scenario 3	Minimize facility	180	n
Scenario 4	Maximize coverage	180	n+1
Scenario 5	Maximize coverage	180	n+2
Scenario 6	Maximize coverage	180	n+3
Scenario 7	Maximize coverage	180	n+4
Scenario 8	Maximize coverage	180	n+5
Scenario 9	Maximize coverage	180	n+6
Scenario 10	Maximize coverage	180	n+7

can be obtained by solving the two problems, LAP and VRP sequentially. By using ArcGIS solution which the heuristic algorithm is embedded in[19], it is possible to find the way to assign all demanding points to UCC considering maximum coverage while minimizing the number of UCC. After assigning all demanding points to UCC, the optimal routes to visiting all demanding points to deliver final products should be developed. The network analysis tool in the ArcGIS, a Tabu search metaheuristic algorithm is applied for all ten scenarios to find the optimal routes with minimum number of vehicles, minimum traveling distance while supporting conditions of capacity of trucks and volume of delivery. The example of the result of network design is depicted in the following Figure 3.

Ⅳ. Result and Discussion

4.1 Result of Location-Allocation Problem and Vehicle Routing Problem

The results of the LAP of all scenarios are de-



1 Choose point layer representing stops to visit
Job sites
2 Travel mode for routes
Driving Time
3 Routes begin at
Start Locations
Route ID field
Driver Name
Start time for all routes
9/1/2016 11:00 AM
4 Routes end at
☐ Return to start
End Locations
Route ID field
Driver Name

Route name	Stop count	Number of truck	Total time (minutes)	Total kilometers
Route_1	36	1	34.57	20.09
Route_2	35	1	72.18	55.98
Route_3	36	1	66.89	58.15
Route_4	30	1	63.12	25.77
Route_5	36	1	31.66	22.23
Route_6	31	1	22.22	16.76
Route_7	36	1	25.72	18.25
Route_8	36	1	58.13	15.32
Route_9	36	1	21.62	12.3
Route_10	36	1	34.6	19.99
Route_11	18	1	52.43	17.57
Route_12	1	1	85.13	81.36
Route_1	4	1	44.88	27.44
Route_2	23	1	29.43	24.51
Route_3	16	1	36.44	28.22
Route_4	6	1	12.07	9.06
Route_5	32	1	23.26	19.87
Route_1	12	1	28.19	22.13
Route_2	36	1	50.65	25.53
Route_3	29	1	23.33	18.7
Route_4	17	1	22.92	16.24
Route_5	36	1	74.88	21.39
Route_6	36	1	98.98	21.28
Route_1	20	1	73.06	50.2
Route_2	25	1	57.37	44.27
Route_3	27	1	56.1	43.76
Route_4	36	1	26.72	20.11
Route_5	35	1	32.31	24.45
Total	757	28	1258.86	780.93

a) VRP Scenario analysis 5

b) Using VRP from ArcGIS online Network analysis tool

c) Using VRP, schedule inspection in Scenario analysis 5

〈Figure 3〉 Example of LAP and VRP for designing network using ArcGIS

〈Table 5〉 Selected UCCs for optimal network for each scenario

Scenario	Number of DC	Analysis Method	Selected UCCs
1	1	-	Without UCC
2	13	Closest Facility	1-13
3	2	Minimize facilities	5 and 13
4	3	Maximize coverage	2, 5 and 13
5	4	Maximize coverage	2, 5, 6 and 13
6	5	Maximize coverage	2, 5, 6, 9 and 13
7	6	Maximize coverage	2, 4, 5, 6, 9 and 13
8	7	Maximize coverage	2, 3, 4, 5, 6, 9 and 13
9	8	Maximize coverage	2, 3, 4, 5, 6, 9, 11 and 13
10	9	Maximize coverage	2, 3, 4, 5, 6, 7, 9,11 and 13

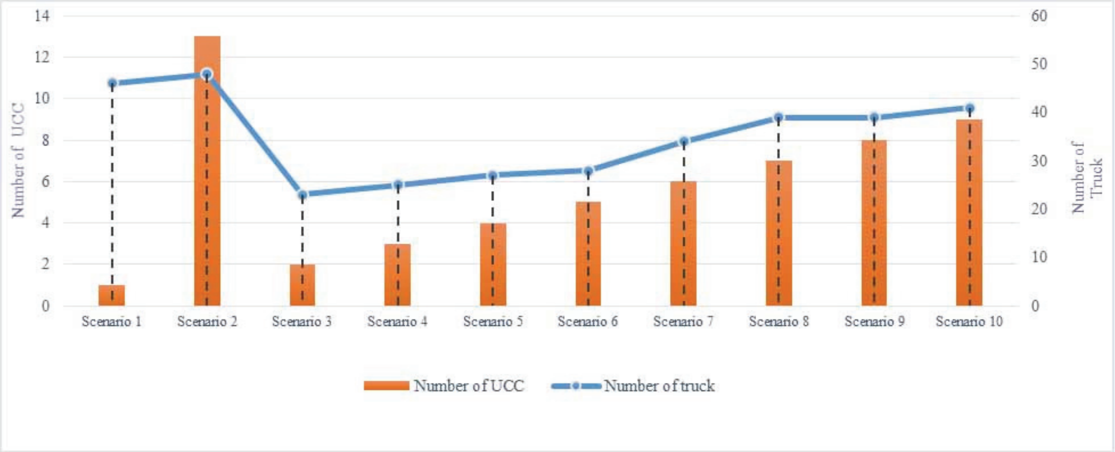
scribed in Table 5 with the selected UCC.

The result of VRP is summarized in Table 6 which shows that the number of required trucks, total traveling time, total traveling distance and improvement of performance compared with Scenario 1.

In Scenario 2, the number of required trucks is higher than other scenarios. Nevertheless, results show that minimum service operation time of 102.58 min. Therefore, it may be that the closest facility solution of the nearest structure determines the transportation cost between demand points and uses optimal facility to determine the closest one. Also, scenario 3 required 23 trucks less than two times Scenario 1. However, Scenario 10 showed the minimum total traveling time (20.50) and total traveling distance (753.06). This result may come from the better delivery route plan and the same equality and fairness for drivers. The remainder, conclusion of this summary, multiple scenario results show that the reduction of the total traveling time and distance due to an optimization goods demand allocated to the optimal location of UCC contributes also to a sustainable perspective.

〈Table 6〉 Summary of performance evaluation

Scenario	Number of Candidate UCC	Max. Lead Time (Min)	Average Operation Time (Min)	Number of Required Trucks	Total Travelling Time (Hr)	Total Travelling Distance (Km)	Improvement compared with Scenario 1 (%)	
							Time	Distance
1	1	-	237.75	46	24.09	985.07	-	-
2	13	-	102.58	48	20.65	764.26	14.27	22.42
3	2	180	219.66	23	21.12	793.66	12.34	19.43
4	3	180	193.78	25	20.89	777.69	13.30	21.05
5	4	180	180.13	27	20.98	780.93	12.91	20.72
6	5	180	181.22	28	21.49	815.24	10.81	17.24
7	6	180	148.87	34	21.29	806.45	11.64	18.13
8	7	180	132.54	39	20.86	780.03	13.41	20.81
9	8	180	126.60	39	20.87	777.59	13.38	21.06
10	9	180	122.31	41	20.50	753.06	14.93	23.55



〈Figure 4〉 Number of trucks and number of UCC

4.2 Comparison of results in terms of capacities

The performance of all scenarios is compared with the number of UCC and number of required trucks in Figure 4.

Figure 4. Number of trucks and number of UCC

The optimal number and the balance of required capacity of UCC are compared in in Figure 5. If we compare the balance of required capacity, it is possible to choose the more stable scenarios.

4.3 Comparison of total cost

For considering the capital budget, the total cost including operating cost and initial investment should obtained at first, which is summarized in Table 7.

In scenario 1 without UCC, it is not possible to guarantee the higher number of required trucks and lower operating costs in UCC and delivery, respectively. Also, in scenario 2 with higher building operation cost and a higher number of required trucks, it is not possible to select this scenario. Regarding scenario 3, 4 and scenario 5, it is interesting that

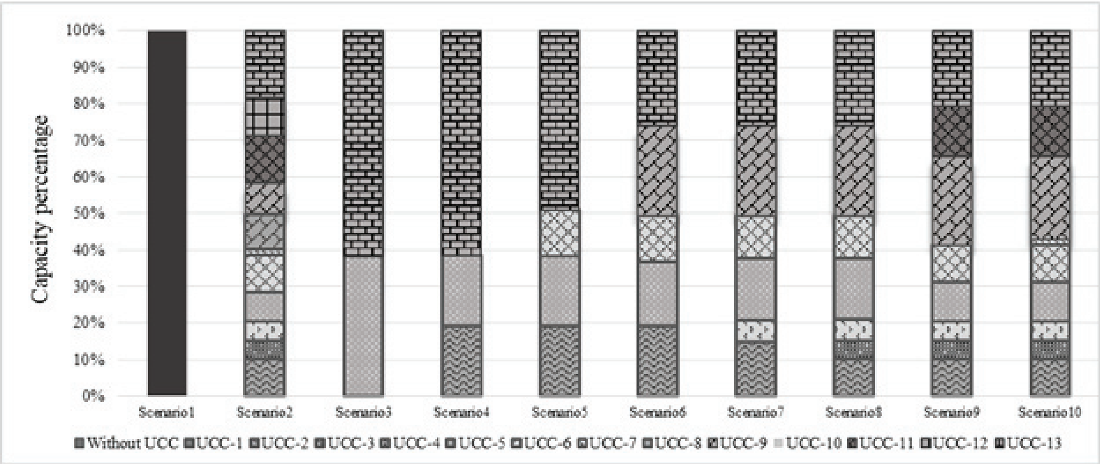


Figure 5. Distribution of required capacity of UCC

〈Table 7〉 The summary of cost comparison

Scenario	Selected UCC	Capital cost annual expense ($)	Operating cost annual expense ($)		Total capital expenditure annual expense ($)
			UCC	Delivery	
1	Without UCC	557.900	437.909	1.574.961	2.570.770
2	1-13	3.924.085	793.087	1.631.886	6.349.058
3	5, 13	1.358.970	381.613	800.674	2.541.258
4	2, 5, 13	1.712.044	441.571	866.575	3.865.994
5	2, 5, 6,13	1.993.671	484.621	933.317	3.020.190
6	2, 5, 6, 9, 13	2.403.880	552.457	968.120	3.411.609
7	2, 4, 5, 6, 9, 13	2.614.042	601.165	1.167.535	3.924.457
8	2, 3, 4, 5, 6, 9, 13	2.811.057	641.119	1.332.877	4.382.741
9	2, 3, 4, 5, 6, 9, 11, 13	3.104.191	675.607	1.332.770	4.785.053
10	2, 3, 4, 5, 6, 7, 9,11, 13	3.269.403	695.704	1.398.296	5.363.403

the number of required trucks and number of UCC is lower than other scenarios. This result may come from the vehicle operating cost and building operation cost being lower than other scenarios. But the average operation time is slightly higher than other scenarios. Therefore, it may be understood that the number of UCC is increased the following number of required trucks should be increased as well.

In Figure 12, “selecting UCC’s equivalent” which implies unbalancing capacity for among scenarios. In candidate UCC-10 is covered only one retailer demand, which it is selected only scenario 2 and take up percentage minimum capacity. Also, Scenario 2, 9 and 10 result of unbalancing capacity among selecting UCC. In scenario 5, 6, and 7 was moderate consensus in the unbalanced capacity. Nevertheless, scenario 3, 4 and 5 evaluated most important scenarios with economic value.

As mentioned before, we have compared the number of trucks and the number of UCCs to determine the core relationship for economic value. Secondly, we have considering the number of UCC's balance of capacity comparing each scenario. In Table 8, it has been presented the result of comparisons of capital budgeting for all scenarios. By considering two main costs below, it shows that the capital cost and operations costs are the scenario showed that total capital expenditure expense. In scenario 2, it shows high-cost value in terms of capital cost and vehicle operating cost. It is clear to understand that the number of UCC and the number of trucks dramatically increased by total capital cost and total vehicle operation costs. Scenario 2, 10, and 9 are needed more investment. As well as, scenario 6, 7, and 8 were average investment required. Interestingly, scenario 3, 4, and 5 evaluated the most important scenarios needed minimum investment value.

Ⅴ. Conclusion

Last-Mile delivery optimization plays an essential role in the urban supply chain performance, it is the most expensive and time-consuming and the most complicated part of the whole delivery process. Therefore, the last-mile delivery is regarded as the major source of traffic congestion in urban areas. Urban consolidation center (UCC) is regarded as a significant asset for supporting customer demand in the last-mile delivery service. The key benefit of UCC is an improving the load factor of vehicles, it is possible to reduce the total traveling distance or find the better route with the well-organized multi-leg vehicle journey in urban areas.

The distribution network for fresh and diary food like milk is not integrated and inefficient distribution network problem. As well as, many of the manufacturing companies, carrier distributing using own fleet, which decentralized supply chain. This independent distribution pattern required additional movement of goods within the urban area, increases worsening challenges congestion, noise, and emissions. Therefore, it becomes the most important strategic plans for retails and logistics business to develop efficient sustainable network.

In this research, we have suggested the scenario analysis for designing optimal distribution network. The framework of this research has integrated the well-known mathematical optimization problems and then analyzed to find the best solution using UCC. In details, the proposed methodology, Locating-routing problem, integrated LAP and VRP. At first, LAP finds the best location of UCC by assigning all the demand. Second, the optimal routes are developed to visit demanding points from UCC. The performance of all scenario is compared based on the several quantitative metrics such as the number of required trucks, traveling distance and time, the number of UCC. Finally, all scenarios were compared with the total cost which consists with operating cost and initial investment for building UCC.

It is required at least two UCC for guaranteeing coverage of all demand points. Regarding scenario 3, 4 and scenario 5, it is interesting that the number of required trucks and number of UCC has a lower than other scenarios. Even though we consider the aspect of capital budget, it defines that the economic value should be considered. In the scenario 2, 10, and 9 with high number of UCC, it is needed to invest more at the initial stage. Interestingly, scenario 3, 4, and 5 evaluated the most important scenarios needed minimum investment value. The remainder, the conclusion of this summary of multiple scenario results show that worst three scenarios are 2, 10, and 9 and the best three scenarios are 3, 4, and 5. The result of this research may come from help the manager or public authorities who should design the distribution network for the last mile delivery service optimization using UCC within urban area.

This research, however, is subject to several limitations such as the proposed methodology we have considered only single type of vehicles and only one type of fresh food. Also, the practical conditions such as average driving speed on different route are not available. Further research could extend this research by considering the future demand and checking the robustness of current solution using sensitive analysis.

References

[1] Shelagh Dolan. “The Challenges of Last Mile Logistics & Delivery Technology Solutions.” Business Insider Intelligence, 2018.

[2] Taniguchi, Eiichi, and Russell G Thompson. City Logistics: Mapping the Future, CRC Press, 2015.

[3] Browne, M., Allen, J., & Leonardi, J. “Evaluating the Use of an Urban Consolidation Centre and Electric Vehicles in Central London.” *IATSS Research*, Vol. 35, No. 1, 1-6, 2011.

[4] Cherrett, T., Allen, J., McLeod, F., Maynard, S., Hickford, A., & Browne, M. “Understanding urban freight activity-key issues for freight planning.” *Journal of Transport Geography*, Vol. 24, 22-32. 2012.

[5] Asian Development Bank. “Breaking Barriers: Leveraging Mongolia’s Transport and Logistics Sector.” Manila, Philippines: Asian Development Bank, 2018.

[6] Allen, J., Browne, M., Woodburn, A., & Leonardi, J. “A Review of Urban Consolidation Centres in the Supply Chain Based on a Case Study Approach.” *Supply Chain Forum: An International Journal*, Vol. 15, No. 4, 100-112. 2014.

[7] Björklund, M., & Johansson, H,. “Urban Consolidation Centre - a Literature Review, Categorisation, and a Future Research Agenda.” *International Journal of Physical Distribution & Logistics Management*, Vol. 48, No. 8, 745-64. 2018.

[8] Sweet, M., Woodburn, A.G. and Allen, J., and Browne Michael. “Urban Freight Consolidation Centres.” Project report. 1: University of Westminster, Transport Studies Group, November 2, 2005.

[9] Simoni, Michele D., Pavle Bujanovic, Stephen D.

Boyles, and Erhan Kutanoglu. "Urban Consolidation Solutions for Parcel Delivery Considering Location, Fleet and Route Choice." *Case Studies on Transport Policy*, Vol. 6, No. 1, 112-24. 2018.

[10] Juthathip, S. "Urban Transportation Network Drsign for Cold Chain Using GIS the Case of Bangkok." Graduate School of Logistic, Incheon National University, 2019.

[11] Keenan, Peter. "Modelling Vehicle Routing in GIS." *Operational Research*, Vol.8, No. 3, 201-18. 2018.

[12] ESRI. Vehicle Routing Problem Analysis (version ArcGIS online). Eng. ESRI, 2019.

[13] Ooluun, V. "Mongolian Milk from Herder's Farm to Your Home." Montsame. No. 20, 2017.

[14] van Heeswijk, W., Larsen, R., & Larsen, A. "An Urban Consolidation Center in the City of Copenhagen: A Simulation Study." *International Journal of Sustainable Transportation*, Vol.13, No. 9, 675-91. 2019.

[15] Van Duin, J. R., Quak, H., & Muñuzuri, J. "New challenges for urban consolidation centres: A case study in The Hague." *Procedia-Social and Behavioral Sciences*, Vol. 2, No.3, 6177-6188. 2010.

[16] Janjevic, M., Lebeau, P., Ndiaye, A. B., Macharis, C., Van Mierlo, J., & Nsamzinshuti, A., "Strategic Scenarios for Sustainable Urban Distribution in the Brussels-Capital Region Using Urban Consolidation Centres." *Transportation Research Procedia*, No.12, 598-612. 2016.

[17] Duin, J.H.R. van, T. van Dam, B. Wiegmans, & L.A. Tavasszy. "Understanding Financial Viability of Urban Consolidation Centres: Regent Street (London), Bristol/Bath & Nijmegen." *Transportation Research Procedia*, No.16, 61-80, 2016.

[18] Scott W., Scott W. "Freight Consolidation Centre Study", South East Scotland Transport Partnership, 2010.

[19] Murray, Alan T., Jing Xu, Zifan Wang, and Richard L. Church. "Commercial GIS Location Analytics: Capabilities and Performance." *International Journal of Geographical Information Science*, Vol. 33, No. 5, 1106-30. 2019.

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