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Designing a Distribution Network for Faster Delivery of Online Retailing : A Case Study in Bangkok, Thailand

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Abstract

Purpose – The purpose of this paper is to partition a last-mile delivery network into zones and to determine locations of last mile delivery centers (LMDCs) in Bangkok, Thailand.
Research design, data, and methodology – As online shopping has become popular, parcel companies need to improve their delivery services as fast as possible. A network partition has been applied to evaluate suitable service areas by using METIS algorithm to solve this scenario and a facility location problem is used to address LMDC in a partitioned area.
Research design, data, and methodology – Clustering and mixed integer programming algorithms are applied to partition the network and to locate facilities in the network.
Results – Network partition improves last mile delivery service. METIS algorithm divided the area into 25 partitions by minimizing the inter-network links. To serve short-haul deliveries, this paper located 96 LMDCs in compact partitioning to satisfy customer demands.
Conclusions –The computational results from the case study showed that the proposed two-phase algorithm with network partitioning and facility location can efficiently design a last-mile delivery network. It improves parcel delivery services when sending parcels to customers and reduces the overall delivery time. It is expected that the proposed two-phase approach can help parcel delivery companies minimize investment while providing faster delivery services.

Keywords: Network Partition, Last Mile Delivery Center, Facility Location.

JEL Classifications: L9, L91, L97, R41.

1. Introduction

Rapid-growing cities have increased globally - cities become "megacities" when people migrate from rural to urban areas within the limited city area. Moreover, cities plan the relocation of public facilities to balance public services in urban areas. Currently, cities emphasize pollution control, especially those pertaining to air pollution and CO2 emissions due to traffic congestion. E-commerce is a significant factor to boost urban freight distribution in urban areas. Olsen, Gergele, Ghee Chua, and Bartolucci (2015) mention that online shopping orders play a significant role in same-day delivery services.

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The parcel delivery industry has been concerned with strategies for one-day or even faster delivery to customers by avoiding traffic congestion in cities and some across-district deliveries. Last mile delivery is required to support short-haul dispatching to end customers. Customer demand is random in a district area, hence it isquite important to cluster demands and to deliver items together in a cluster for efficient deliveries of items. The clustering manages routing and grouping of customers, and it evaluates groups and routes to tranship parcels in a district area. When the areas are partitioned into zones, the parcel delivery companies locate freight delivery centers in each zone to handle local pickup and delivery requests.

However, the disadvantage of demand clustering is the overlapping of service when sending parcels to customers. Most of previous clustering methods focus on grouping of points and overlapping of clusters were not important issues. If carriers are forced to dispatch multiple parcels separately in the same area, it will be difficult to maintain the current last-mile delivery system due to overlapped activities in parcel delivery. Grouping demand will be useful to help the carrier deliver services economically because it can support routing for carriers and easy-to-manage directions to customers. Barreto, Ferreira, Paixão, and Santos (2007) performed a clustering analysis to solve a capacitated location-routing problem. Neither overlapping of clustering nor crossing border areas are a concern in the cluster methodology. This avoids the main factors of last mile delivery service such as traffic congestion, reducing CO2 emissions, the speed of service, and customer satisfaction.

At present, the parcel delivery industry focuses on small-scale services to distant low-density customers shopping online. Guadalupe (2009) states that the activities of parcel delivery consist of pickup and the delivery of packages within a service region. The various customer locations disturb the service distribution every day. Even though administrative district borders can be used to separate service areas, it is impossible to guarantee effective clustering of areas. In the current borders of administrative public districts, there may be an area and route overlap for the same location. Therefore, district borders are not sufficient for parcel service and effective clustering of demand points and delivery facility location problem should be optimized regularly.

This paper pays attention to last mile delivery service for serving a parcel in urban areas. We designed the service network with contiguous network partitioning and facility location to help carriers deliver parcels to customers efficiently by addressing how to minimize inter-network and maximize intra-network deliveries and by balancing the workload and reducing the overlapping area. Contiguous network partitioning of demand areas is determined by a clustering algorithm and, once we have partitioned zones, we optimize the location of facilities to serve each partitioned zone. Facility location algorithm can allocate required resources to each zone by locating last-mile delivery centers properly.

Therefore, this paper studied how to avoid the overlapping problem by focusing on network partitioning and how to locate last-mile delivery centers in each partitioned zone. We created a new partition by applying a mathematic model and approached a facility location problem for a suitable dispatching process for the parcel delivery industry. With this two-phase network design approach, we can efficiently operate last-mile delivery services for online orders. Since the network structure of demand areas such as roads and houses does not change frequently, the network partitioning phase can be applied in a long term and when demand changes the facility location phase can provide effective re-arrangement of facilities in the partitioned demand areas. In this paper we propose a logical and systematic two-phase network design approach and this integrated approach will help the parcel delivery industry manage their last-mile delivery network more efficiently.

2. Literature Review

2.1. Last-mile Delivery Services

Faster delivery refers to last mile delivery service to send a parcel to a customer. E-commerce has increased while technology is important to lifestyle (Morganti, Dablanc, & Fortin, 2014). Smartphones can be everything, such as a department store, stock market, and calling taxi, among others. As mobile commerce becomes popular, e-commerce become easier to access and growth of e-commerce skyrocketed (Choi & Yang, 2018; Lee, 2017).

Thus, it produces fast orders to a carrier who delivers packages to the end-customer. This is increasing shipment services in "last mile"as a final service to a customer in the supply chain (Schewel & Schipper, 2012 Amchang & Song, 2018). To increase customer satisfaction, it is important to build brand and reputation in e-commerce industry and the delivery service quality becomes one of key factors since the time gap between order and delivery is not negligible in online shopping (Hwang & Lee, 2011; Kim, 2017; Lee & Feng, 2015).

In Europe, alternatives of delivery networks have improved in countries such as Sweden, Norway, Finland, and Denmark (Morganti et al., 2014). They provide approximately 5000 distribution points to support E-commerce and delivery service to the end customers. Last mile deliveries are majorly impacted by traffic congestion in the city area (Iwan, Kijewska, & Lemke, 2016). Thus, parcel carriers need some more points to support their last mile service such as a parcel locker or another center that can improve the last mile service.

In Asia, offline retail infrastructure is not well established and online commerce play a key role for economic growth due to easier access to products and lower prices (Phuong & Dat, 2017; Prashar, Verma, Parsad, & Sai Vijay, 2015; Rahman, Ismail, Albaity, & Isa, 2017; Singh, 2014; Su & Youn, 2011). When customers buy online, they expect the same level of services compared to offline purchase. However, pre-mature offline retail infrastructure of emerging economies, especially in Asia, gives online e-commerce opportunities to grow faster. In addition, online and offline companies collaborate to provide innovative solutions to customers. Faster and economic deliveries will help companies develop creative commerce solutions.

Under this environment, last mile delivery centers (LMDCs) become key facilities to support last mile delivery service (Amchang & Song, 2018). LMDC are located in a dense city area and a faster delivery service is available. For faster delivery, short distance service and short time-windowfor delivery are important. As such, LMDC is an alternative for solving distance limitation and increasing the efficiency of last mile delivery. However, to place LMDC in an appropriate area is rather challenging and at times, the size of the area effects the last mile service in the city area.

2.2. Network Partitioning

To evaluate a service zone, clustering should be determined based on the location and coverage set of facilities to be served, and the demand in many locations (Liao & Guo, 2008). Graph partitioning is an important application in data clustering which applies a graph model (Ding et al. 2001 Aggarwal & Wang, 2010) Graph theory is mostly applied to detect a complex community network. Malliaros and Vazirgiannis (2013) provide that a different type of data can create abundant networks, such as the Internet, telephone networks, and road networks. As partitioning demand is applied to deliver service, it can support routing for carriers and can make it easy to manage direction for customers. Barreto, Ferreira, Paixão, and Santos (2007) provide a clustering analysis concerned with solving a capacitated location and routing problem. Cotilla-Sanchez et al. (2013) applied sub-graphs partitioning to power systems, where large systems are divided into areas and zones for planning and controlling its application. They approached a graph partitioning algorithm to partition a power network by optimizing electricity. In a partitioning algorithm, communities are necessary for network systems as it is a social network (Newman, 2013). Thus, communities in an area can refer tourban road networks as a result of population migration. Anwar, Liu, Vu, and Leckie (2014) state that these networks are growing considering different sizes in traffic flow patterns. The aim of this paper is to estimate network partitions of different patterns in traffic congestion based on a novel graph cut ($\alpha - Cut$) to partition the graph. The branch-and-cut routine has been used to formulate the edges and node partition (Ferreira, Martin, de Souza, Weismantel, & Wolsey, 1998).

Anwar et al. (2014) explained a different graph partitioning, such as a road network which is a real urban road network that transforms into a set of intersection points as it is nodes connected by a set of directedroad network. Moreover, a road graph gains more information by adding each road segment and establishing an undirected link between each node. Therefore, network partitioning can reduce service overlapping by dividing areas/zones. It supports the service of last mile delivery by avoiding traffic congestion, reducing CO_2 emission, and improving the speed of service and customer satisfaction when goods are sent to end-customers. When clustering or grouping a service zone, previous researchers considered a distribution center to be a limiting factor as the locationof a customer closer to a facility center is expected to be a priority to serve.

Depending on the grouping, its demand is proximity to distribution center. It can be a disadvantage solution as the overlapping service will occur when sending a parcel to customer. Somehow sending goods to different grouped of orders but overlap in routing or service direction. This problem also impacts the balance of work load capability of manpower, delivery time, loading, and routing. Moreover, the carrier will force double links to dispatch a parcel in the same route to customers.

2.3. Facility Location and Parcel Delivery Network Design

Barreto et al. (2007) applied a clustering analysisto minimize the routing and location costs by considering a set of potential capacitated distribution centers and a set of ordered customers. Kalcsics, Nickel, and Schröder (2005) designed a territory by grouping a small geographic area into larger cluster then approached a classical location-allocation. However, they are rather a different fromour paper as some of them do not consider the partitioning stage first before a place facility center.

As such, this paper pays more attention to network partitioning to design a service zone and then tries to find a positionto place an LMDC to support last mile service in a compact partition. Even though we got a compact size of network partitioning but the last mile delivery needs a facility center to serve a high quality of delivery service. LMDC is a necessary factor to improve a service level of parcel delivery service (Amchang & Song, 2018).

Thus, we applied a formulation of health care and point of dispatching (POD) facility location to be a concept. Amchang and Song (2018) state that LMDC is different to UCC; thus, the location concept of UCC will not be adapted in this paper. The facility location of an emergency service is similar to LMDC as it serves short-haul distance or short service time and is located inside a densearea. For example, home health care (HHC) is an important part of the logistics decision at a present. Gutiérrez-Gutiérrez and Vidal (2015) provides a service network design to deliver a medical care to patients' homes. Balanced workloads of staffs are necessary for each district to supply items and medicines to patients. Lee, Chen, Pietz, and Benecke (2009) determined locations for POD facility by implemented Real Opt software for simulation. This paper adapted the formulation of Lee et al. (2009), since health care pod facility location problems are quite similar to our problem. As explained in Anand, Quak, van Duin, and Tavasszy (2012), under urban logistics environment, it is important to consider operational, tactical and strategic constraints altogether.

Most of parcel delivery network design research have focused on the hub network design under hub and spoke network structure (Jiang, Sun, Li, Lin, Zheng, & Shen, 2017; Lin & Lee, 2018; Serper & Alumur, 2016). The parcel network design problem typically consists of two parts including background hub-and-spoke design phase and last-mile delivery phase. Kafle, Zou, and Lin (2017) studied the last-mile crowd-sourced delivery network design problem and Lim and Koo (2016) analyzed cost efficiency and demand patterns in parcel delivery center locations and service areas. Wang andMu (2015) proposed a methodology to optimize a distribution network design under the collect-on-delivery setting. It has been assumed that network partitions and facility locations are given before analyzing the network design. Therefore, we applied a two-phase approach including network partitioning (strategic level decision) and facility location (tactical level decision) together. Network structures such as roads and boundaries does not dynamically change while population density and online e-commerce demands change over time. Phased approach with network partitioning and facility location will enhance efficiency and effectiveness of network design approach.

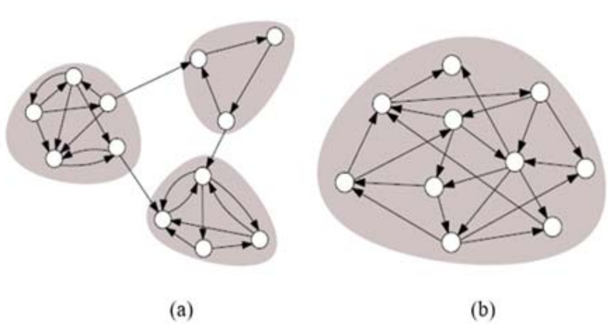
3. Research Methodology

3.1. Network Partitioning Formulation

In this paper, we considered density-based clusters because it plays a larger role in the tradition of community networks, both directed and undirected. This notion of density-based clusters is depended on the distribution and topology of the edge of the network. It is defined as a group of nodes with more intra-cluster than inter-cluster edges (Girvan & Newman, 2002; Newman & Girvan, 2003).

As <Figure 1> (a),presents a directed network contains three density-based clusters. The edge density within each cluster is much larger than density between different clusters. In contrast, <Figure 1> (b) shows a directed network with uniform edge distribution among nodes. This network lacks an organization.

Therefore, the goal of a graph clustering algorithm is to assign the nodes to clusters by maximizing the number of edges within clusters, all while minimizing inter-cluster edges. Moreover, we designed a formulation to edge-clusters. The objective function is as follows: (1) To maximize the intra-edges in each cluster by minimizing the inter-cluster edges. Constraint (2) ensures that every node is added to a cluster. Constraint (3)-(4) ensure that each node is connected. Constraint (5) and (6) are to balance service in each cluster.



<Figure 1> The first network (a) consists of three density-based clusters, while the second network (b) shows a homogeneous link density with the absence of an obvious community structure (Malliaros & Vazirgiannis, 2013).

The notations of this formulation including

E : a set of edges between sub-district i and j,
S : set of sub-districts,
K : set a of cluster partition,
L_{ij} : the inter links between node i and j,
E : the edges between node i and j,
P_i : population in node i,
C_k : capacity of partition k.

The mathematical formulation for demand clustering can be given as following.

$$\text{Minimize} \quad \sum_i \sum_j L_{ij} y_{ij} \qquad \forall\, i,j \in S \tag{1}$$

$$\text{S.T.} \quad \sum_k x_i^k = 1 \qquad \forall\, i \in S,\ \forall\, k \in K \tag{2}$$

$$x_i^k - x_j^k \le y_{ij} \qquad \forall\, i,j \in E,\ \forall\, k \in K \tag{3}$$

$$x_j^k - x_i^k \le y_{ij} \qquad \forall\, i,j \in E,\ \forall\, k \in K \tag{4}$$

$$\sum_i P_i x_i^k \le C_k \qquad \forall\, i \in S,\ \forall\, k \in K \tag{5}$$

$$x_i^k, x_j^k, y_{ij} = \{0,1\} \qquad \forall\, i,j \in E,\ \forall\, k \in K \tag{6}$$

We analyzed this formulation by utilizing the Xpress-MP software, but we could not get a result because of the limitation of the software to analyze a big set of data. Therefore, we applied METIS algorithm to solve this problem instead.

3.2. METIS algorithm for Contiguous Network Partitioning

According to Karypis and Kumar (1998), METIS is an algorithm for partitioning large irregular graphs and large meshes and for computing fill-reducing orderings of sparse matrices. METIS is based on the multilevel graph partitioning which has been shown to quickly produce high-quality partitioning. The paradigm includes three steps: graph coarsening, initial partitioning, and uncoarsening. In the coarsening phases, vertices will be matched to maximize the size of adjacent pair sets. After that, METIS runs partition phases and partitioning of the coarsest and hence, smallest. In this phase the graph is using relatively simple approaches. At the end of the procedure, the smallest graph partitions are projected to the associated larger graphs in the uncoarsening step.

METIS is used for reducing the size of the graph, and its algorithm will refine a high-quality partition from three steps. This software can partition an unstructured graph into number k of parts or the multilevel k-way partitioning followed by a user-specified. Moreover, for multilevel k-way partitioning, the algorithm provides a result as minimize subdomain connectivity graph and ensures contiguous partitions or minimizes alternative objectives.

3.3. Facility Location Formulation

To design a last-mile delivery network, we first create sub-districts into network partitions as explained before. Once we have balanced set of network partitions, we need to locate facilities in each zone. To locate facilities, it is necessary to solve a facility location problem. In this paper, we propose a facility location formulation, which can be efficiently solved by a commercial optimization solver such as xpress-MP. In addition, to assume service distance, we found a suitable distance for last mile service at approximately 8–15 kilometers (Polzin, 2017). Based on this assumption, we will apply approximately 10 kilometers to be a maximum service constraint. The parameters in the model include

Let k : the total number of partitioning
G_i : set of nodes in partition i
d(r,l) : distance between nodes r and l
d_{max} : maximum allowed for last mile service distance
C_l : the capacity of the LMDC at node l
p_r : population of node r.

Decision variable
$y_l = 1$ if LMDC site at node l is selected for setting up a facility, 0 otherwise;
$x_{rl} = 1$ if the population in node r is served by the facility at grid l, 0 otherwise.
We can formulate the LMDC location problem as follows:

$$\text{Minimize} \quad \sum_i \sum_j L_{ij} y_{ij} \qquad \forall\, i,j \in S \qquad (1)$$

$$\text{S.T} \quad \sum_k x_j = 1 \qquad \forall\, i \in S,\ \forall\, k \in K \qquad (2)$$

$$x_i^k - x_j^k \le y_{ij} \qquad \forall\, i,j \in E,\ \forall\, k \in K \qquad (3)$$

$$x_{j^k} - x_{i^k} \le y_{ij} \qquad \forall\, i,j \in E,\ \forall\, k \in K \qquad (4)$$

$$\sum_i P_i x_{i^k} \le C_k \qquad \forall\, i \in S,\ \forall\, k \in K \qquad (5)$$

$$x_i^k, x_j^{k,} y_{ij} = \{0,1\} \qquad \forall\, i,j \in E,\ \forall\, k \in K \qquad (6)$$

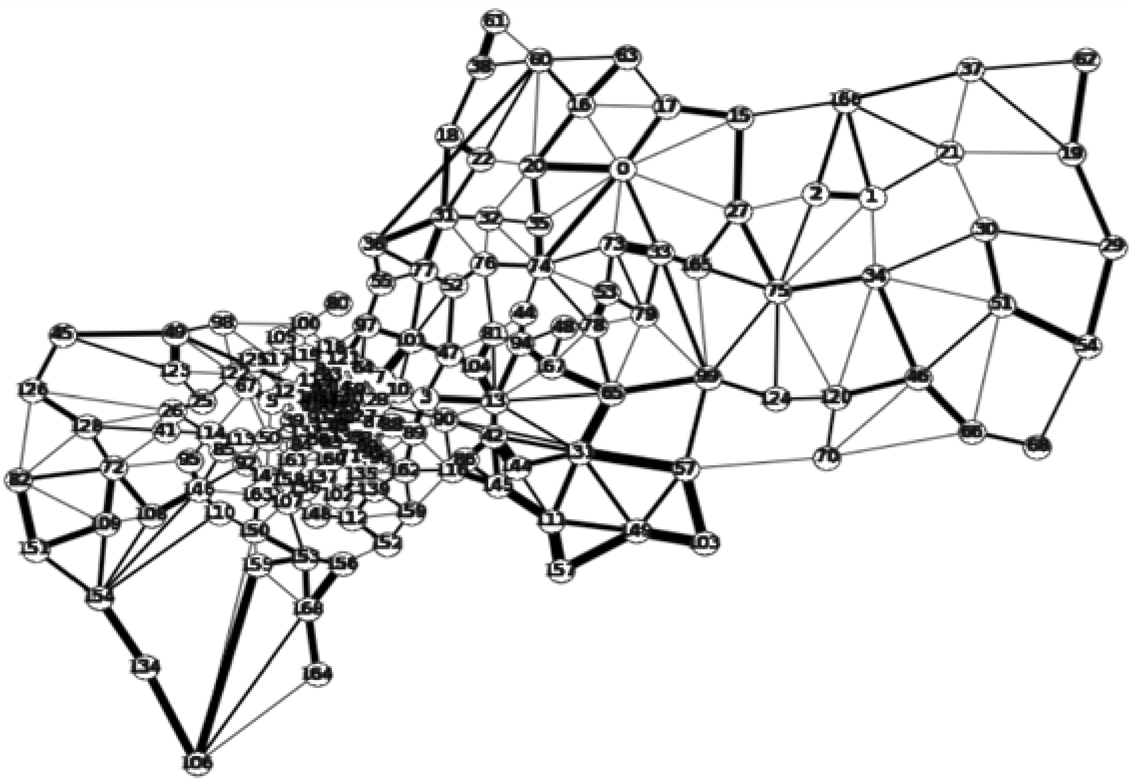
The objective of this formulation is to minimize an LMDC to serve a customer under the following constraints: (2) ensures that at least two LMDCs are opened. This is for improving customer satisfaction. Constraint (3) ensures that a maximum distance for dispatching a parcel to the end customers is at most d_{max} kilometers. Constraint (4) ensures that each LMDC is served, and constraint (5) represents the workload of the LMDC. We utilized the Xpress-MP software to solve this problem.

4. Case Study in Bangkok, Thailand

Bangkok is ranked second globally in terms of the amount of traffic in the city (TomTom Traffic Index, 2016). Thus, it takes time for an individual to travel though Bangkok's urban area. Considering a parcel carrier, it is challenging to control the service time of last mile delivery. Moreover, the population of the city has been increasing since 2010; therefore, increasing number of people result in traffic congestion and pollution in the city (Amchang & Song, 2018). As online shopping is an important criterion to increase last mile service (Olsen et al., 2015), parcel companies such as Ninja, Kerry Express, and Nim Express have established their businesses in Bangkok. These carriers have designed a strategy to provide efficient last mile service to customers. For instance, Kerry Express installed a parcel shop by using the Asoke station to serve as a parcel counter service to support customers (customer business: C2C). Ninja is a new parcel company and pays more attention to sending a package only in the Bangkok area and has designed its strategy as 45 minutes delivery time to customers in the city area.

The competition between parcel delivery companies in Thailand is high since the E-commerce market also boomed. However, the traffic congestion problem is a major factor to provide last mile service in the wide area in Bangkok. Therefore, the resizing of the service area has become a necessary factor to be considered in last mile delivery service. For instance, Kerry Express expanded its service by adding more delivery centers to support short-haul service. It provides variety of services, such as parcel shop, parcel locker, parcel customer service, and distribution center. These refer to parcel delivery industries in Bangkok, Thailand its needs to create last mile service efficiency by finding a strategy to design short distances service and it can cover order demand while balancing of capability.

The case study for this paper took place in Bangkok, Thailand. At present, the parcel industry in Thailand is rapidly growing because of online shopping and e-commerce business. Therefore, new parcel companies have been established for last mile delivery service, and they have created a strategy to improve customer satisfaction. Most of the last mile services do not concern themselves with network partitioning they pay more attention to clustering customer demand. To cluster demand, the first priority is where a facility will be located and then to find demand close to the facility and to group this demand under a user-condition. We realized that this methodology has the overlapping of services between each cluster. In some cases, delivery will not increase a freight beneficial of service because the contiguity of each cluster has been not considered.



<Figure 2> Bangkok network before partitioning

We collected real data from commercial GIS software and Thailand government websites. Detailed geographical data such as road and sub-district shapes were collected from GIS software and demand data such as population and density from government websites. We calculated the detailed number of nodes and links, which were input data for METIS and facility location optimization algorithm from the geographical data. In the test data set, we have 169 sub-districts and approximately 380 roads that translate to 169 nodes and 380 edges-links in METIS algorithm.

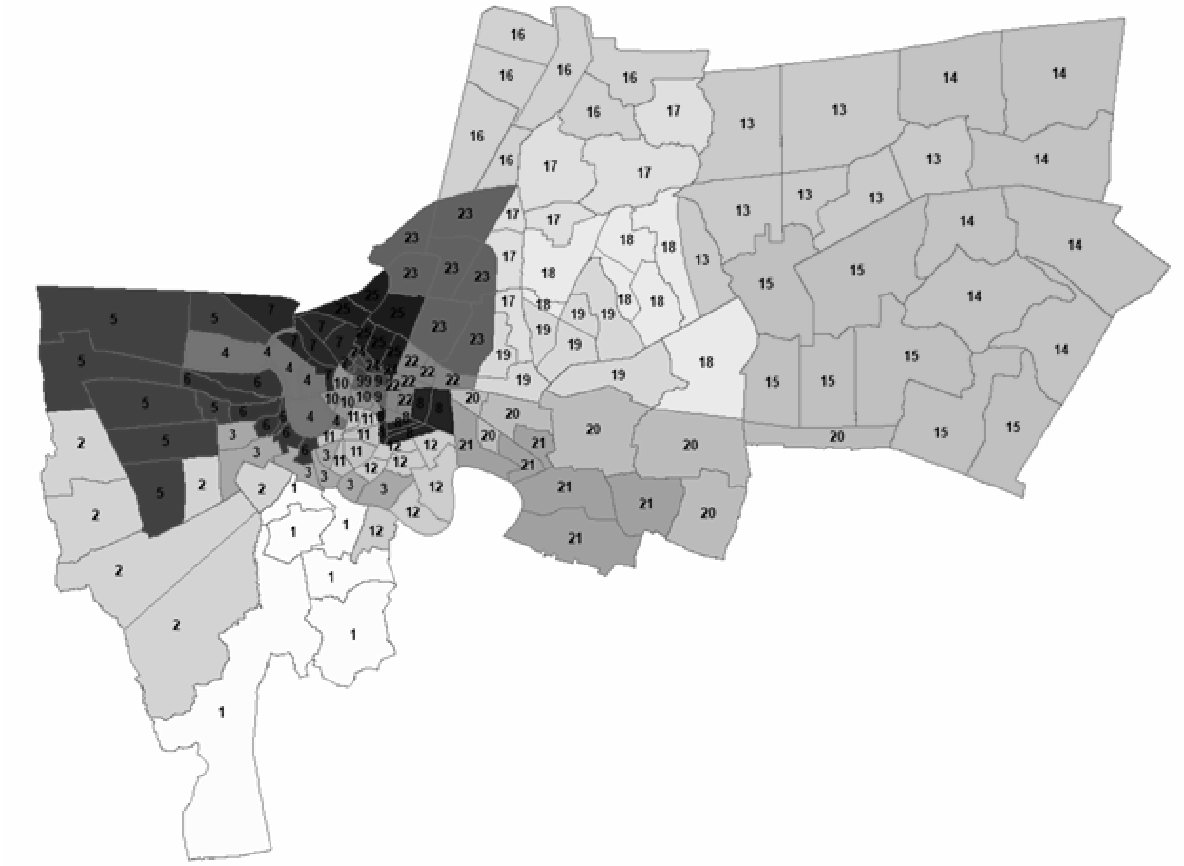
We assumed five scenarios to define a relationship between different k-way partitioning with last mile delivery services. The network of Bangkok is illustrated in <Figure 2> and it shows nodes, links, and weight on edges inside. Thicker links mean that the adjacent sub-districts have more links between them and they are tightly interconnected. It is important to group these tightly interconnected areas into a partitioned zone.

The input data includes 169 nodes and 380 edges. Then, we assumed five different scenarios in the METIS algorithm. Each scenario has different number of target partitions. For example, under the first scenario, we are trying to partition the whole area into five zones. The results are illustrated in <Table 1>. It shows the number of inter-partitioned edges as they are being minimized. From five scenarios, the 25 partitions can maximize the communication level of intra-edges and high quality to minimize the edge cut of inter-links.

<Table 1> Results from the METIS algorithm

Scenarios	Target Partitions	Edge cut	Intra-partition edges
1	5	89	68
2	10	165	119
3	15	349	194
4	20	370	231
5	25	391	255

<Figure 3> shows that all the nodes are placed in one of the partitions. Thus, it resulted in a suitable service area for serving a parcel delivery in Bangkok, Thailand as it followed high quantity of edge cut. This means that if inter-edges are cut significantly, minimizing of the objective function is successful. After analysis by METIS, the mesh data file divides the network vertices by the partitions as illustrated in <Figure 3>. It illustrates each node that is put into each partition. Furthermore, we approached the Geo Information Systems software (GIS) by transferring a result from network partitioning to a map. Since, the visualization from the map is easy to understand, and it illustrates which node is in each partition. As shown in <Figure 3>, the sub-district is designed in a new zone and it is a contiguous partition. Based on the analysis, we ensured that each partition has a maximum network movement of transportation inside. It can solve both traffic congestion and reduce a delay of dispatching in each partition.

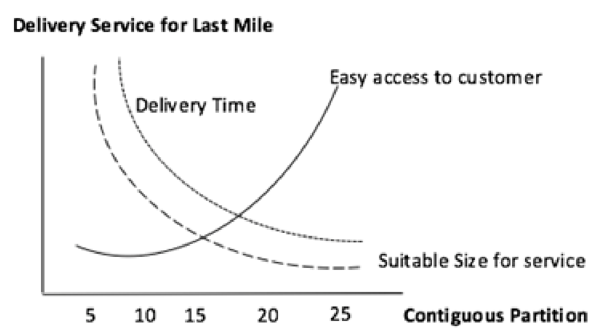


<Figure 3> The result from a 25-partition by METIS in a map by GIS software

This concept is better for companies that want to establish a new last mile delivery center or expand their service into another area. If companies evaluate a partitioning zone to be optimally sized, the service will cover a smaller size and easily have access to the customer. The idea of our paper is important to decision makers of parcel companies who are considering their future plans and want to redesign their last mile service.

Moreover, we realized the following relationship based on this information: if parcel companies want to improve their last mile service, companies need to be concerned about how easy it is for customers to have access to the service and how to reduce delivery time. The amount of contiguous partition is a significant factor to evaluate the size of a last mile service. The partition size fluctuations direct delivery time. Therefore, if a small partition decreases the delivery time of a last mile service, it means that parcel companies can create a short distance service by providing various types of instruments for delivering a parcel to customer, such as a mini-van, bicycle, motorcycle, and walk to last mile service.

Therefore, last mile services can directly send parcels to customers in a short timeframe and improve customer satisfaction, as explained in <Figure 4>. Choi and Lee (2012) state that customers prefer supply networks which are closely localized to support a good delivery service.



<Figure 4> The relationship between contiguous partition and last mile delivery service

From 169 sub-districts, the LMDC will be located around 96 positions and it can serve a parcel service in 10 kilometers and under a workload balancing condition, as shown in <Figure 5> and <Table 3>. The satisfaction will be improved because the service can be covered in each partition with a compact size in the shortest distance. It reduces delay of service time and it is easy to directly send parcels to customers.

This paper assumed five k-way scenarios to find a maximum of edge cuts and a minimum of inter-links. The partitioning in 25 k-way show a better result of high edge cuts and high communication level. Moreover, the contiguous of each partition is important to a last mile service when dispatching a parcel to customers. After that, we applied a facility location problem to our research. To figure out a location of an LMDC in a partitioning area we adapted a formulation from (Lee et al., 2009) to evaluate a location for an LMDC in Bangkok. This research is recommended for companies who want to expand their business to other areas, and it will be concerning network partitioning at first sight. The network partitioning helps a decision maker to re-organize the service zone and delivery service and to then find a location to place an LMDC in a suitable area. Since distance, time, and workload of the carrier are concerning in this industry, these constraints are combined in this formulation. In Bangkok, we will be locating LMDCs around 96 positions and all customers within 10 kilometers of each network partition will be covered.

The number of LMDCs in Bangkok

Partition ID	LMDCs	Partition ID	LMDCs
1	5	14	3
2	4	15	4
3	5	16	5
4	4	17	4
5	4	18	5
6	3	19	4
7	3	20	4
8	4	21	5
9	3	22	2
10	3	23	5
11	3	24	3
12	3	25	4
13	4	Total	96

The implication is given based on the results of this research. Overlapping of demand clustering will be decreased if network partitioning from METIS is applied. It is helpful for the decision maker to locate a LMDC inside. A contiguous partition was guaranteed by METIS and the access to customers will be easier than in a non-contiguous location. However, the limitation of this paper is data, as we cannot get original data from a parcel company. For future research, real data will be applied and simulated for an LMDC location.

<Figure 5> The location of LMDCs in Bangkok

5. Conclusions and Discussions

As online commerce grows, customers demand more frequent and faster delivery of orders. This requires more trucks dispatched to congested urban areas which cause problems in the perspective of traffic and environment issues as well as efficiency of network management. To manage the parcel delivery network, it is important to locate smaller freight handling facilities inside city logistics network. This paper proposes a two-phase network design algorithm including network partitioning and facility location to design the last-mile delivery service network in urban areas.

The proposed two-phase algorithm consists of the network partitioning phase and the facility location phase. Since network structure such as roads and locations of demand points does not change rapidly within a short time period, the network partitioning phase focus on dividing the network into smaller zones considering the given network structure. The objective of the first phase is to minimize inter-zone links, which is helpful to cluster demands considering geographical structures. Clustering becomes an important method to dispatch a parcel to the end destination. However, overlapping of the network occurs when transporting a package to the customer and it creates an unbalanced workload of the carrier. Demand clustering is always concerned with how to group customers close to a facility center by avoiding creating a service zone. The network partitioning from the METIS algorithm can be a solution to solve this problem. METIS solved this problem through 3 steps: coarsening phase, partition phase, and uncoarsening phase. These steps were refined until getting a solution as a set of objective function. The second phase is to determine the location of LMDCs in partitioned zones to balance resources and workloads. Facility location formulation minimizes the number of LMDCs while satisfying demands in each partitioned zone. The second phase tries to balance infrastructure investment and operational service quality.

The proposed methodology has been tested with a case study from the data, Bangkok, Thailand and showed that it can optimize the network partitioning and facility location problem. The case study illustrated how to set the parameters for the methodology and how to analyze the given problem. The recommended network partitioning differs from the original borders of administrative districts. The partitioning gives minimized inter-zone activities and maximized intra-zone activities. Congested areas are grouped together into smaller zones and sub-urban areas grouped in wider zones.

This idea is recommended to parcel companies who want to expand their business to other areas or who want to establish a new LMDCs but have not yet identified a location. Especially, when the parcel companies deal with faster delivery in congested urban districts, the proposed methodology with network partitioning and facility location provides a guideline for designing urban network systems into a compact area. Moreover, it reorganizes the service zone and delivery service for fast online order fulfillment regardless of administrative district borders. The compact size of partitioning helps to support a last mile service in a traffic-congested area. The parcel delivery industry can control the direction, service time, and balance their service capability. Customer satisfaction would increase as customers obtain goods in shorter of time.

However, the case study was analyzed with publicly open data obtained from GIS software and government websites instead of parcel companies. Thus, the behavior and management strategy for the problem might be a bit different in a real situation. For example, small size LMDCs may be located in the middle of a city but may have a large capacity of service. Even though the proposed network partition analysis and a case study in Bangkok provides the location decision preference of urban network for faster online in last mile service, it has geographic limitation as well. The implication is that this paper needs more data in a real capacity of LMDCs. It would be an interesting research to compare the analysis result between other parcel companies in other countries as well.

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