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# The Coverage Area for Extended Delivery Service in Eastern Economic Corridor (EEC): A Case of Thailand Post Co., Ltd\*

Chompoonut AMCHANG\*\*

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## Abstract

**Purpose:** This paper aimed to study the current locations of post offices to analyze service coverage area for parcel delivery in the Eastern Economics Corridor (EEC), which must be considered in the last mile to extend delivery service for e-commerce growth. Thailand Post was the case study in this paper. **Research design, data and methodology:** To involve solving the delivery service area under the last mile condition, the authors proposed a network analysis to determine service radius by employing a Geographic Information System (GIS). Furthermore, this paper applied Dijkstra's algorithm as a network analysis tool from GIS for analyzing the last mile service coverage area in a new economics zone. At the same time, the authors suggested an approach as a solution to locate last mile delivery center in EEC. **Results:** The results of the study pointed out that Thailand Post should consider more last mile delivery centers in EEC to support its express service in urban areas as well as improve the efficiency of service coverage for parcel delivery and create more advantages against competitors. **Conclusions:** This paper proposes a network analysis to extend the last mile service for parcel delivery by following Dijkstra's algorithm from GIS and a solution approach to add more last mile delivery centers. The results of the research will contribute to boosting customer satisfaction for last mile delivery service and enabling easy accessibility to a service center in EEC.

**Keywords:** Geographic Information Systems, Service Area Analysis, Last Mile Delivery, Eastern Economic Corridor, Parcel Delivery Service

**JEL Classification Code:** L8, L81, L87.

## 1. Introduction

Nowadays, online shopping has become a popular form of e-commerce business. Customers can buy goods and services using websites and mobile applications. Online shopping has multiple options allowing customers to select products and services from domestic as well as overseas providers (Chung, 2017). The e-commerce development in Thailand has seen continuous growth. It has become vital to gaining more competitive benefits in regional and global business. Therefore, the parcel service business in Thailand has also seen a dramatic increase in growth. This shows that delivery service companies need to improve their service to match the demands and transportation requirements for courier segmentation. Since consumer behaviors tend to

change, parcel delivery services in Thailand are motivating domestic and international private transportation companies to establish business in the Thai market, such as Thailand Post, Kerry Express, CJ Logistics and Yamato SCG. However, service comparison between parcel delivery companies involves high competition. Particularly in a new economics zone, an Eastern Economics Corridor (EEC) is an important zone for investment in new businesses and communities. Thailand 4.0 is a significant strategy that will power this zone (Legislative Institutional Repository of Thailand, 2017).

Short delivery service comparison is a strategy for parcel delivery companies to provide more customer satisfaction. Still, it is very difficult to create a service under city expansion. This is because the parcel delivery companies that send products into a dense area with traffic congestion from a city may experience increased delivery times. Therefore, parcel delivery companies need urban logistics infrastructure to improve their express delivery services.

According to the current number of service centers and distribution centers operated by Thailand Post, there are less when compared to competitors (Janglom & Tantipidok,

\*This work was supported by Faculty of Logistics, Burapha University, Thailand.

\*\*First Author, Ph.D., Lecturer, Faculty of Logistics, Burapha University, Thailand, Email: [chompoonut@go.buu.ac.th](mailto:chompoonut@go.buu.ac.th)

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2020). The problem focused on in this research is that the service coverage area of Thailand Post in EEC is insufficient to support e-commerce business and the last-mile delivery service concept. Thus, this research will be performed under the presumption that service coverage area is necessary for Thailand Post to extend deliver service in EEC. Thailand Post should also consider the locations of post offices for better distribution of parcels to customers.

The main contribution of this research can be categorized two perspectives. First, the author analyzed the current situation of parcel delivery in Thailand based on the public sector. More specifically, the author studied the service area of locations for post offices operated by Thailand Post in EEC. Based on the study, insightful information can be gained to help the decision-makers who select the locations of post offices to consider service area. Second, the author suggested a last-mile delivery service framework for the parcel delivery business. This research applied Geographic Information Systems (GIS) to analyze the service coverage of current post office locations. The results of analysis may help decision-makers to consider a number of new locations for post offices to better support the increasing demands of courier delivery service.

In this paper, the authors introduce an extended last mile delivery service center for parcel delivery companies in a new economics zone as Thailand Post. In Section 2, the authors provide a literature review and an overview of last mile delivery, as well as geography information systems (GIS) with Dijkstra's algorithm and service area analysis. In Section 3, a network analysis is provided by applying a Geographic Information System (GIS) following Dijkstra's algorithm in a case study. In Section 4, the authors suggest a solution to implement last mile delivery centers. Section 5 provides a concluding suggestion and further research topics.

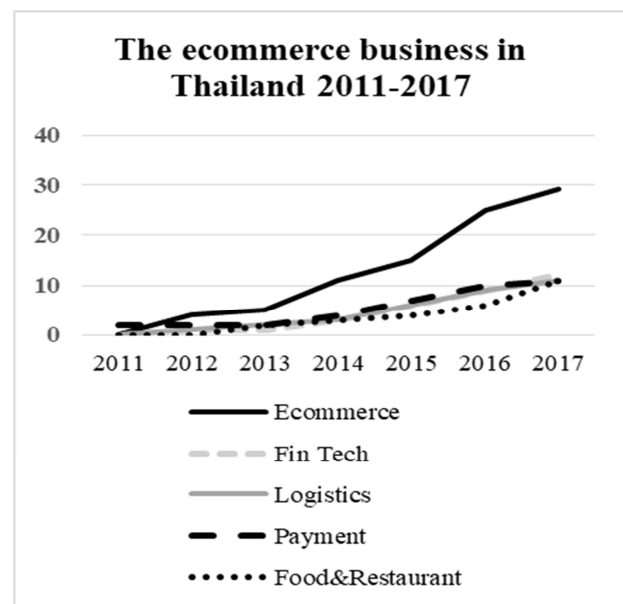
## 2. Literature Review

### 2.1. E-commerce in Thailand

Thailand is the second-largest economy in Southeast Asia in terms of the business-to-customer (B2C) segment. Moreover, e-commerce has become a driver for courier delivery. The growth of e-commerce has caused changes in buyer behavior in Thailand. Accordingly, customer-to-customer (C2C) segments have become necessary for service using online channels. Customers need products delivered directly and with a short waiting time. As a result, social commerce has been developing along with courier express because there is a need to adapt to faster delivery service.

Recently, the Thai government announced "Thailand 4.0"

as an economic model that will enable Thailand's economic growth. Thus, it is a key policy for driving the country's economic growth, boosting the industrial sector, and improving the quality of life for all citizens. The size of the e-commerce market in Thailand can be motivated and influenced by foreign investment. There are various international investors in the Thai e-commerce market such as Alibaba, JD.com, Shopee and Lazada. Therefore, the e-commerce category is leading to more foreign investments when compared to other categories Figure 1. Moreover, Thailand has around 57 million people who are internet users, accounting for 82.4 percent of the total population. Around 70 percent of users visit online retail stores and around 62 percent actually purchase products and services online. Thailand is one of the world's largest social commerce markets. It was reported that 51 percent of online shoppers that purchased a product or service does so via a social channel such as Facebook or LINE.

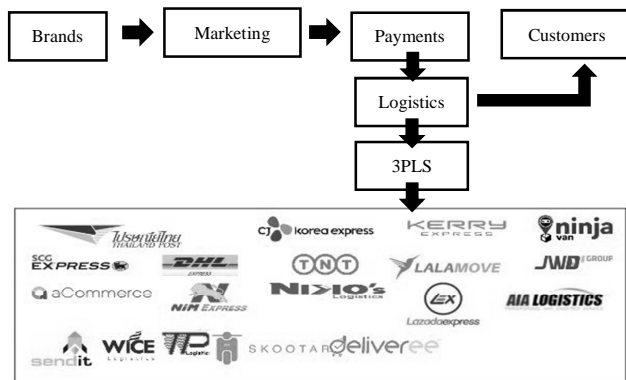


Source: Prateepsawangwong & Luo (2018)

Figure 1: The e-commerce business in Thailand

In the e-commerce business, it is important for success to deliver goods or services to end consumers accurately and promptly. Thus, any successful strategy for e-commerce must include delivery service for sending packages in an efficient and timely manner. Third-party logistics providers (3PLs) play an important role in the shipment and delivery of goods. Delivery cost is one main reason why e-commerce players turn to 3PLs. In the segment of third-party logistics, there are also foreign investment companies, meaning the competition in the delivery service market has strong comparisons. Thailand has several logistics

providers such as Thailand Post, Kerry Express, and DHL, among others. There are also social media delivery platforms such as LINE MAN, GRAB, and LALAMOVE. Thailand’s e-commerce platform for parcel delivery companies is shown in Figure2. The beginning of upstream is brand product creation, followed by marketing and advertising to customers, resulting in product purchases. From a logistics perspective, 3PLS take products and delivers them to customers (Amchang, 2018).

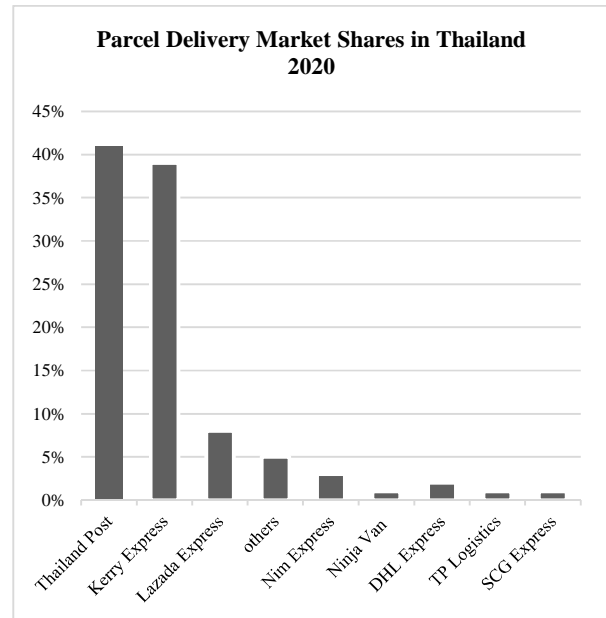


Source: Amchang (2018)

Figure 2: E-commerce platform and parcel companies in Thailand

The competitive reality of parcel delivery in Thailand currently involves more price competition. The 3PLS of parcel delivery service consists of 3 major players occupying over 80% of the market, including Thailand Post, Kerry Express, and Lazada Express. There are other medium players such as SCG Express, DHL e-commerce, Nim Express and Ninja Van. In addition, many large players from abroad have invested in the Thai delivery service market, such as Best Logistics, which comes from the Alibaba group in China. J&T Express is the number one carrier from Indonesia, while CJ Logistics, a carrier from South Korea, has a joint venture with JWD InfoLogistics (JED) of Thailand. Moreover, the carriers have opportunities to face competition from on-demand delivery, which provides express service within an hour from Lalamove, Lineman, and Grab Express. However, on-demand delivery focuses on users who need immediate delivery of goods, which is different from the past. On the other hand, on-demand delivery has limitations in terms of short service distance in urban areas such as the Bangkok metropolitan area or other dense areas. There are different market shares for parcel delivery companies in Thailand, as in Figure3. In fact, Thailand Post holds 41% of the market share, while Kerry express holds 39% and Lazada Express holds 8%(Janglom & Tantipidok, 2020). This means that Thailand Post has significant competition with other last-mile delivery service players. Thus, Thailand Post must

develop its service to customers to remain competitive.



Source: Janglom and Tantipidok (2020)

Figure 3: Market share breakdown of parcel delivery in Thailand

Table 1: Comparison of centers for last-mile service providers (3PLS)

3PLS	Start Business	Service Center	Consolidation Center	Distribution Center
Thailand Post	2003		-5,000	25
Kerry Express	2006	10,000	1,300	10
Lazada Express	2016	-800		57
Flash Express	2017	2,000		85
J&T express	2018	1,100		15
CJ Logistics	2018	80		<120
Best Express	2019	2,200		>500

Source: Janglom and Tantipidok (2020)

The speed of last-mile delivery has also been developing for the last 5-7 years. 3PLS should maintain the delivery speed for sending parcels to customers because parcel delivery companies may lose customers if there is any delay in delivery. Thus, the 3PLS should consider increasing more network locations to keep suitable service area responsiveness to carriers. Most 3PLS play more attention to increasing the number of delivery centers and

distribution centers for their businesses, as in Table 1. Even though Thailand Post was established before other 3PLS, the number of service centers and consolidation centers operated by Thailand Post is less than Kerry Express. Therefore, delivery service to close this gap in designation should be considered by Thailand Post.

### 2.2. Last Mile Delivery Service

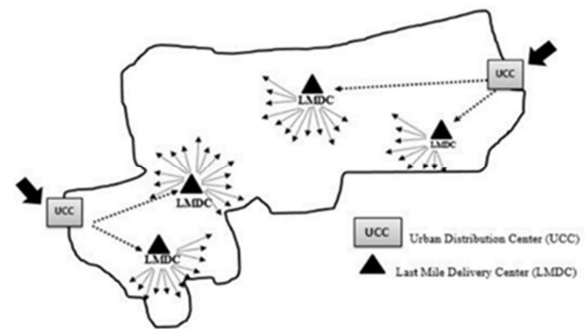
E-commerce is one main industry affected by delivery service change. Amchang & Song (2018) last-mile delivery service refers to faster delivery to send goods to end customers at a short distance. Nathanail, Gogas, & Adamos (2016) describe last-mile delivery as the movement of people and goods from a hub to a final destination, such as a home or business office. Nabot & Omar (2016) offered that last-mile delivery is related to delivery in terms of CO2 emissions in shopping modes. Architectures, Chips, & Najafi (2015) stated that last-mile delivery plays a more important role when considering the number and location of intermediate depots for sending parcels to destinations. Thus an optimal fleet and size of vehicle types should be considered to serve an urban area.

Typically, the definition of last-mile delivery center (LMDC) means a location inside a city and close to a densely populated area. It can ensure flexible speed of service when demand and time are uncertain and also help mitigate CO2 emissions and congestion in dense areas. LMDCs are not created to replace other centers, but rather to support the urban distribution center and improve the efficiency of last-mile delivery (Amchang & Song, 2018b).

In European countries, they provide around 5,000 distribution centers to support last-mile service. In megacities, last-mile service faces traffic congestion, which can impact delivery time (Iwan, Kijewska, & Lemke, 2016). Thus, parcel service needs more centers for supporting the last-mile concept. City logistics has become a trend to apply the last-mile concept in cities. CO2 emissions and traffic congestion need to be mitigated in cities. There are various options for dispatching a parcel in a city to increase customer satisfaction, such as by bike, drone, and electric vehicle (Amchang & Song, 2018b; Leesa-Nguansuk, 2016). The concept of a small vehicle provides the fastest possible delivery time without producing CO2, which is necessary for last-mile service. LMDCs comprise a significant point for distribution of parcels to customers in a city, ensuring speed and flexible routes for delivery. A suitable distance for last-mile delivery is approximately 5-15 kilometers, as found by previous research in Table 2.

Moreover, most 3PLS has been applied to improve customer satisfaction by reducing delivery time. For instance, the Monaco government has applied a consolidation center to support electric vehicles inside the

city (Binsbergen & Visser, 2001). Other European countries have considered last-mile delivery by influencing stakeholders to adopt this concept in their business (Kayikci, 2010). Furthermore, Olsen, Gergele, Ghee Chua, & Bartolucci (2015) applied the last-mile concept to one-day delivery service for supporting online shopping orders. LMDCs always apply urban consolidation centers (UCC) to improve the efficiency of courier distribution Figure 4. Thus, both consolidation centers are supported together to deal with the growth of e-commerce (Arvidsson & Pazirandeh, 2017).



Source: Amchang and Song (2018b)

Figure 4: Difference in perspective between UCC and LMDCs

Table 2: Review of suitable last-mile delivery distance

Reference	Objective	Distance	Type of Service
Allen et al., (2018)	To require the exacting delivery services offered by e-retailers	11.9 km.	Last mile operation
Lopez (2017)	To study the current situation of last mile distance of logistics infrastructure	9.5-14.5 km. (6 to 9 miles)	Retailer
Farhan & Murray, (2006)	To develop a model for coverage in location facilities	6.44-8.05 km. (4 to 5 miles)	Recycling facilities
Mallick & Routray, (2001)	To prepare coverage for interpretation and in planning for decision maker	5-10 km.	Rural service center

For 3PLS that want to implement last-mile service in cities to increase satisfaction from consumers in the delivery service, last-mile delivery service has become a solution to reduce delivery time while increasing service coverage in a city area.

For instance, Raphaëlle, Paristech, & Delaître (2013) explained that urban freight transportation has become necessary to optimize the movement of good in a city. Due to changing customer demand, new logistics strategies and innovation for distribution have become necessary. Thus, the last-mile delivery concept needs to be updated for the parcel delivery sector. In France, Faccio & Gamberi (2015) studied a field analysis of questionnaires for door-to-door

services to identify the performance of eco-logistics systems. It was also developed into Vicenza Province in Italy. The distribution of goods in urban areas under traffic congestion is considered to be linked to energy consumption, air and noise pollution. Ewedaïro, Chhetri, & Jie (2018) studied the map measurement of potential transportation networks by applying last-mile delivery (LMD). A map is used for spatial measurement by considering the road network and planning controls. It presents the mapped output with the urban area in traffic congestion and needs LMD to implement urban planning and city logistics. Moreover, Oliveira, Oliveira, & Correia (2014a) explained that the increase in a population and development in Belo Horizonte, Brazil was related to city economics. So, it applied simulation and optimization to implement a potential logistics system and reduce the impact of goods movement in the city. Moreover, Amchang & Song (2018) applied the last-mile delivery concept to improve customer satisfaction in a dense area. The most suitable distance for last-mile delivery is typically between 5 -15 km.

**Table 3:** Summary of literature review: last mile delivery; service area coverage

Reference	Objective	Methodology	Sector
Oliveira et al., (2014)	To analyze urban logistics space	Simulation, Optimization	Private
Perboli, Rosano, Saint-Guillain, & Rizzo (2018)	To illustrate the framework	Simulation, Optimization	Private
Ewedaïro et al., (2018)	To measure and map of the potential last mile delivery	GIS	Public (ecommerce)
Cárdenas, Beckers, & Vanelander, (2017)	To study demand of B2C delivery	Costs calculation	Public (ecommerce)
Flisek & Lewandowicz, (2019)	To modify an algorithm for mapping linear service areas	ArcGIS (Linear barriers)	Private
Mallick & Routray, (2001)	To prepare coverage service area	GIS	Public
Yang, Goerge, & Mullner, (2006)	To analyze the radius of service area according to the type of provider	GIS (gravity model)	Private (HealthCare)
Manerba, Mansini, & Zanotti (2018)	To organize a fast delivery under a different time window situation	Minimize traveled distance	Public (Home Delivery)

In summary, the literature review presented in Table3 shows that there are several previous researches that have examined various solutions to analyze the problem concerning coverage of service area. In these previous studies, optimization in travel distance and cost considerations was the primary approach. Moreover, GIS has become a tool to analyze the last-mile service in different functions. However, only a few previous studies involved the exact locations of parcel delivery service centers and real service coverage among the positions for last-mile centers. Therefore, it is not easy to find adequate research focused on the public sector in terms of parcel delivery in Thailand. Moreover, not many studies compare the differences in service coverage for last-mile service under the e-commerce situation.

### 2.3. Eastern Economics Corridor (EEC)

Eastern Economics Corridor (EEC) is a government policy that supports trade competition, investment, and the distribution of goods and services. This economics zone increases economic competitive capability by elevating technology and innovation, thus boosting quality of life for citizens (Office of The National Economic and Social Development Council, 2016). In Thailand, EEC has included 3 provinces: Chonburi, Rayong, and Chachoengsao. When combining these three provinces, the total area is approximately 13,404 sq. km in Figure5.



**Figure 5:** Illustrates studied area in EEC

EEC is located in a suitable location for the Thai economy because its area is close to two airports including Suvarnabhumi airport and Utapao airport. Thus, it is suitable for import and export businesses. Moreover, Chonburi is a province in EEC where Leamchabang port is located. For either sea transportation or rail transportation,

EEC offers multimodal transport in this area (Office of The National Economic and Social Development Council, 2016).

EEC has become a zone of trade competition. So, the free-trade movement of products, services, investments and skilled laborers is important to the economic zone. Therefore, this zone will be its own mega-city in Thailand. People and industries will move into the area. So, the e-commerce trend will be the most important business and is also related to transportation in terms of parcel delivery service. EEC is a place many industries want to gain entrance. In the case of parcel delivery service, 3PLS companies need infrastructure planning for extended last-mile service. However, the improvement of last-mile service infrastructure is easy for private companies because they can adapt and implement the last-mile strategy based on trends. On the other hand, Thailand Post is a public sector company, meaning it takes more time to develop the last-mile delivery concept.

#### 2.4. A case study of Thailand Post Co., Ltd

Most parcel delivery companies in Thailand are in the private sector, so they can improve delivery service for the e-commerce trend easily, unlike the Thailand Post, which is a state enterprise business handled between government and company. It provides delivery services for parcels, letters, and other aspects of product movement from transportation. So, Thailand Post takes time to improve the infrastructure of its service and develop its delivery service. In fact, it has prepared a strategy before implementing the service for customers (Lertrit, 2010). With the growth of e-commerce, there has been an effect on logistic sectors since the behavior of customers has changed towards online shopping. So, it has a significant impact on the delivery service sectors. Therefore, this paper considers the last-mile service of Thailand Post in EEC. Thailand Post owns 1,275 postal facilities in Thailand. In this paper, we applied only 56 post offices in EEC comprising pick-up and distribution centers for parcel service. Therefore, Thailand Post needs to consider the last-mile delivery service size in the future. To facilitate faster delivery, Thailand Post should first study how the service areas for delivery centers can offer coverage for domestic and international customers (ThaiQuote, 2017). So, EEC is important for Thailand Post by adjusting and planning its service to cover parcel demand in the future.

Therefore, the difference between Thailand Post's services and last-mile delivery can be divided into 3 dimensions. First is the coverage of delivery service. Thailand Post uses long-distance service to cover all areas but doesn't consider the delivery waiting time for the destination. Second is the fewer post offices, meaning it cannot provide fast speed to customers. It is difficult for the

shortest accessibility. Third is less transportation consideration of CO<sub>2</sub> emissions. Therefore, Thailand Post should develop its services to increase customer satisfaction and improve the efficiency of its parcel delivery process.

### 3. Research Methods and Materials

#### 3.1. Study Area

For the purposes of this study, Thailand Post in EEC is selected as a case study to suggest a coverage area for the last-mile delivery concept. EEC identifies a gateway for a new economics zone in Thailand, which will be a megacity. So, Thailand Post may deliver inside the city with last-mile delivery delay and bottlenecks in transportation. In addition, Thailand Post needs a condensed city model for serving last-mile delivery to customers in a crowded city.

#### 3.2. Datasets

The data collection for this paper needs spatial data to apply to GIS methodology. It is divided as below:

- Location of post office: In this paper, we applied 56 post offices that related to last mile activities. The 56 post offices are located in EEC.

- Province of EEC: EEC included 3 provinces comprising Chonburi, Rayong, and Chachoengsao.

- Transportation networks: This data is important for analysis in the GIS method. It is necessary to create geodatabase for network analysis to consider service coverage area.

- Population: The purpose of this paper is to extend last-mile service into a city area. Population can refer to a suitable location for a post office with specific population density. Thus, the population in each district is assumed to correlate with the demands of parcel service.

The data analysis of this paper is categorized into 3 processes: first, spatial data is analyzed into a geographic coordinate system. In this case, Thailand uses universal transverse mercator (UTM) projection. Second, we manage network analysis to be the main function to analyze route, distance, and suitable service area. Network analysis can be a tool for analysis of several problems. Thus, this paper proposes the service area analysis. Third, non-spatial data analysis is applied to describe data processing in GIS. A data table is needed to determine statistical values.

#### 3.3. Research Model

Geo-Information Systems (GIS) is a process using spatial data through a computer system. It is used to determine data and information to analyze geographical

data (Thongkham, 2016). This geographical system is different from other programs because it uses location data and descriptive data in the analysis (Satiennam, Fukuda, & Oshima, 2006). There are many papers applied this method. White, Guy, & Higgs (1997) used GIS to develop the accessibility of post office service by an underlying population. The impact of rural service was considered as well. Kimpel, Dueker, & El-Geneidy (2007) studied the overlapping of bus stop service areas by considering the walking service area of the bus stops. Distance was applied to estimate walking accessibility to the bus stops. The analysis of a method is applied for one-quarter-mile service under uniform density demand. Mallick & Routray (2001) applied GIS for preparing coverage in the interpretation of planning and decision-making in India. The results showed that suitable distance could be used to determine the service area between a market and health center. The radius of service was shown to be within 5 km. GIS is useful for creating a database for spatial planning and for applying in the field of urban and regional development. Moreover Amchang & Song (2018a) applied GIS to visualize the spatial data of a transportation network and the shape of sub-districts to analyze facilities locations for last-mile delivery centers (LMDCs). Therefore, GIS is a powerful method for analyzing spatial data that is better than other methods.

This paper proposes the research framework as shown in Figure 6. **Step 1:** we prepare data and data collection concerning post offices, road networks, provinces, and population data. In this step, we need to transform to spatial database as point, line, polygon, and network dataset. **Step 2:** we overlay a shape file then analyze the population data with post office locations into GIS software. **Step 3:** we create a network analysis layer for preparing the next step. **Step 4:** we analyze a service area through network analysis while considering the last-mile concept. In this step, we approach 3 distances that are suitable for last-mile service as 15km., 10km., and 5km. The service analysis in this step is followed by Dijkstra's algorithm to find last-mile service at a short path distance. **Step 5:** we suggest a number of post offices for supporting the last-mile concept of Thailand Post into EEC.

### 3.4. Research Model

The network analysis function in GIS follows Dijkstra's algorithm. This paper applies GIS as a tool to prepare the spatial database and run an analysis of service area coverage to Thailand Post for last-mile service of EEC. The ArcGIS desktop application is required for the network analysis function. Its function involves using the Dijkstra algorithm to analyze service area with the short path condition of the algorithm in Figure 7.

#### 3.4.1. Dijkstra's Algorithm in network analysis of GIS

The algorithm of Dijkstra tries to find the shortest distance or service area. So, network  $G = \{V, E\}$  when  $V(G)$  is a set of nodes in graph  $G$ ,  $E(G)$  is a set of arcs in graph  $G$  and  $d_{uv}$  represents the length of line  $(u, v) \in E$ , which processes in the method (Dijkstra, 1959; Klawwikarn & Jirakajohnkool, 2014). The lines use a continuous line graph and the weight of all lines have to be over 0. This means that  $w(u, v) > 0$  in all  $(u, v)$  and  $E(G)$  is specified, where  $S$  is assigned to be a set of vertexes by having a default value of an empty set,  $d_v$  is a value of distance from the starting point to vertex point  $v$ , and  $Q$  is a set of vertexes that have not been entered into the loop.

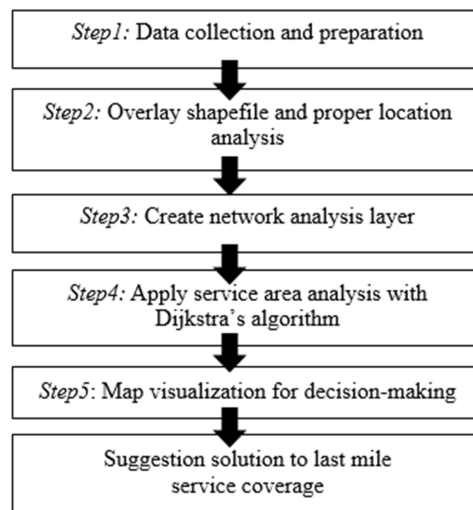


Figure 6: Research framework

The default value is  $V(G)$ . Point  $u$  would be selected into the loop. It would be the point that appears in  $Q$  with the lowest  $d_u$  value. Once selected, this point would be removed from  $Q$  and the value would be applied to  $S$  instead. A review would be made on every point  $v$  that has a line connected from point  $u$  if  $d_v > d_u + w(u, v)$  then make a change to  $d_v = d_u + w(u, v)$  and edit the point to vertex  $v$ . It comes from point  $u$  then repeats in the loop until  $Q$  then becomes an empty set, which allows the shortest route to be achieved as desired (Kongyong, 2012).

Service area analysis is used to apply Dijkstra's algorithm to the traverse network. The objective of this tool is to return a subset of connected edges to specify a network distance or cost cutoff. The service area can generate polygons, line that surrounding this both. The polygons from the service area are generated by using the geometry of lines then traversing into a triangulated irregular network data structure (ESRI, 2017). Many papers have studied the

application of Dijkstra’s algorithm to find short distance service. For instance, Baltic (2015) applied Dijkstra’s algorithm for the delivery of courier items or express delivery. Flisek & Lewandowicz (2019) modified the algorithm for mapping a service area. Network analysis is used to generate a service area based on points and road networks. Spatial data is applied to design the size of the service area. Moreover, Chukwuka, Abiodun, & Emmanuel (2018) proposed a route planning application by using Dijkstra’s heuristics to analyze the shortest path algorithm in routing. It pays more attention to emergency responses during disasters, fire outbreaks and courier package to reduce logistics cost in the transport sector. Short path distance is important not only in express transport, but also emergency response by adapting Dijkstra’s algorithm to route network analysis (Ahmed, Ibrahim, & Hefny, 2018).

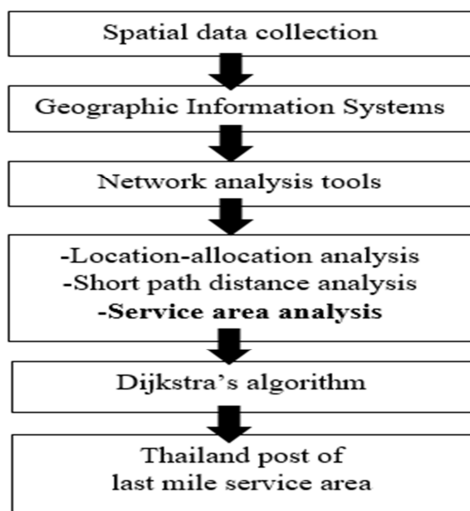


Figure 7: Research Methodology

### 4. Results and Discussion

This spatial database is the basis of network analysis for the last-mile service area in the case study. Base on the outputs, a service area for last-mile delivery is carried out applying GIS. To explain the results of this paper, we divide them into 3 parts: first, we study population expansion in EEC, after which we show the locations of the post offices that address the density of the area. Second, we analyze service distance that is matched with the last-mile delivery concept. Third, we suggest the appropriate number of post offices in the case study to expand last-mile service.

#### 4.1. Determine the population expansion in EEC

For the locations of post offices in EEC, we apply 56

post offices that provide last-mile delivery. Post offices are located in a good location with availability to access network transportation in Figure8. In this stage, we add more layers of population in EEC to analyze post office locations and area density. The post offices have been located in proper positions with population density Figure9.

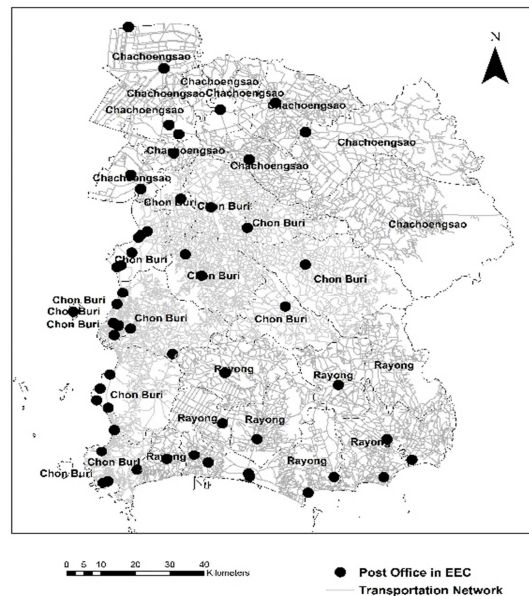


Figure 8: Location of post offices in EEC

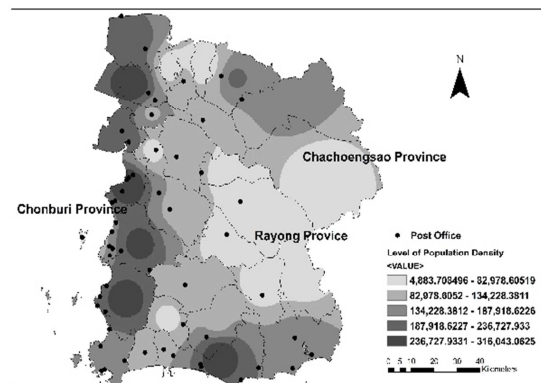


Figure 9: Location of post offices in dense areas.

The level of dark color means areas have varying population densities. For the density analysis, we utilize GIS software to combine the spatial database.

#### 4.2. Network analysis to service area

This paper uses GIS to analyze the service area to apply short path distance theory by Dijkstra’s algorithm from the

GIS method. In this stage, we apply 3 dimensions of last-mile delivery distance such as 15km., 10km., and 5km. These three categories of distance were collected from the literature review as those that would be a proper distance for last-mile service in urban areas. The result shows that, if Thailand Post wants to extend last-mile service from 56 post offices, then it requires adding more LMDCs in the study area, as necessary in Figure10.

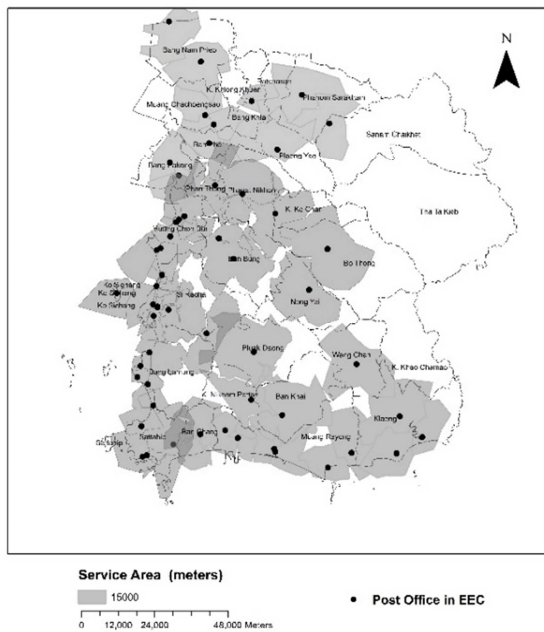


Figure 10: 15 km. service area of last mile

For short distance service, Thailand Post cannot improve the efficiency of its parcel service due to lack of LMDCs. Due to the service area being 15 km., the map presents the locations of post offices not located around EEC. Thus, the coverage of last-mile service at 15km. will not cover the entire area. Moreover, if Thailand Post wants to address more last-mile coverage in short patch distance as 10 km. and 5 km., the map of the service analysis presents that Thailand Post needs as much LMDCs as possible, as shown in Figure11 and Figure12.

The results of service area analysis from GIS suggest the strategy for last-mile delivery to Thailand Post. It involves implementing more LMDs depending on what service sizes are needed because individual service size takes a different number of LMDCs being located. Table4 explains the percentage of coverage area to last-mile service at a different service distance. The result explains the varied radius of service size that needs less LMDCs. If Thailand Post plans to be a 3PLS of parcel delivery in EEC, however, it needs to reduce service size by locating more LMDCs.

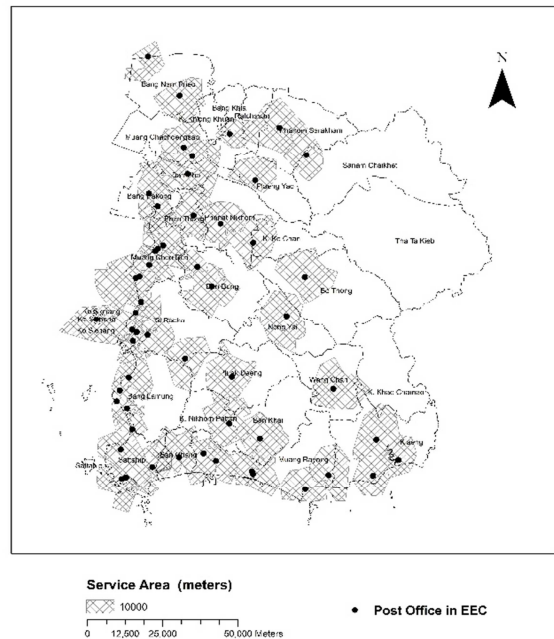


Figure 11: 10 km. service area of last mile

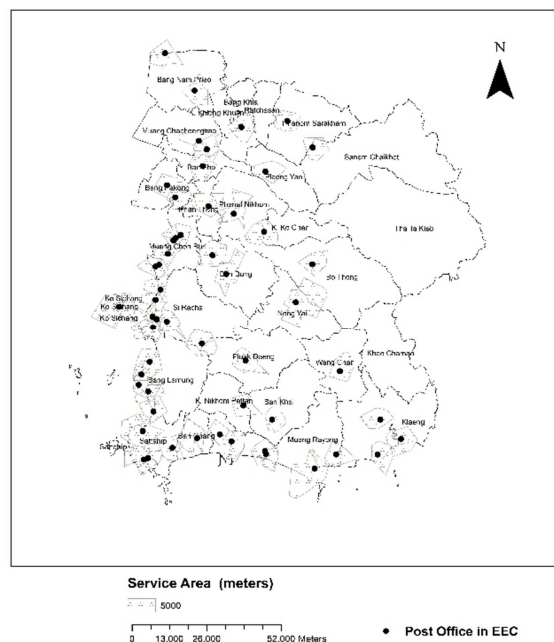


Figure 12: 5 km. service area of last mile

The percentage of last-mile coverage service distance shows the size of service is dependent on the number of LMDCs. The 15 km. distance covers around 67% of service size in EEC, 29%, and 16%, respectively. In the case study, Thailand Post only has 56 post offices for last-mile

activities. Therefore, 15 kilometers for distance service is the first step to implement, followed by creating more last-mile infrastructure for 10 km., and 5 km. respectively.

Therefore, the current locations of post offices can cover the area in the EEC, as in Table5. The results were calculated by using GIS.

**Table 4:** Percentage of service area coverage in different ranges

Province	No. post office	Total area EEC(km <sup>2</sup> )	Total area (%)		
			5 km	10km	15km
Chonburi	31	4,476	35	38	89
Chachoengsao	14	5,226	5	18	39
Rayong	11	3,702	9	35	79
Coverage EEC area (percentage)			<b>16</b>	<b>29</b>	<b>67</b>

**Table 5:** Total coverage area of current post offices

Province	No. post office	Total area EEC (km <sup>2</sup> )	Coverage Area (km <sup>2</sup> )		
			5 km	10km	15 km
Chonburi	31	4,476	1,578	1,712	3,989
Chachoengsao	14	5,226	264	951	2,029
Rayong	11	3,702	336	1,280	2,929
Coverage EEC area (km <sup>2</sup> )			<b>2,178</b>	<b>3,943</b>	<b>8,947</b>

**4.2.1. An analysis of numbers of post office**

This paper suggests a number of LMDCs for Thailand Post to increase last-mile service size. In EEC, Thailand Post has only 56 centers related to the last-mile concept. However, the locations of its centers do not cover the whole EEC area. Therefore, Thailand Post needs to address more LMDCs into EEC. In this topic, we calculate a proximity number for last-mile service centers by comparing between the existing number of post offices and service area coverage from network analysis, as shown in Table6.

**Table 6:** Expected number of LMDCs for Thailand post in EEC

Province	No.Post office	Total area EEC(km <sup>2</sup> )	Estimate number of post office for last mile delivery		
			5 km	10 km	15 km
Chonburi	31	4,476	88	81	35
Chachoengsao	14	5,226	277	77	36
Rayong	11	3,702	121	32	14
Estimate post offices in EEC			486	190	85

To estimate the number of post offices for last-mile delivery in EEC, it can be calculated by using information about the number of current locations in each service distance multiplied by the total area of each province in EEC, then dividing by the coverage area of the current location in a different distance of last-mile service. Based on the service analysis, LMDCs are important to expand

delivery service in a city. So, this case study needs to add more LMDCs into the city area to cover last-mile service for different last mile distances. The result presents the number of post offices that are needed to address EEC. So, the estimate for post offices on 15 km., 10km., and 5km. of service size is 85 centers, 190 centers and 486 centers, respectively.

E-commerce provides buying options for customers, including providing many opportunities for delivery service to 3PLS. Urban logistics becomes an important concept for delivery service in a city. Particularly, parcel delivery plays more attention to last-mile service companies who launch into the business sectors. Last mile infrastructure is necessary to support parcel service in a dense city. Therefore, a last-mile consolidation center becomes a micro center to address the inner city to increase the service size for last-mile delivery. Due to traffic congestion, CO<sub>2</sub> and PM2.5 affect both citizens and delivery service companies. Consequently, many countries are paying more attention to policies for reducing traffic congestion in the city and letting delivery companies consider CO<sub>2</sub> emissions in the city. Therefore, last-mile concepts are launched into urban areas, which refer to the short distance of service that can be applied for parcel delivery. Moreover, online shopping is another motivation factor in courier delivery for considering the last-mile concept by avoiding traffic congestion and improving customer satisfaction. GIS is a tool used to apply a network analysis by considering service area under last-mile conditions. The service area analysis followed Dijkstra’s algorithm from GIS software. Therefore,

this method can be used to solve service size for the last-mile delivery concept and the number of location of LMDCs in the case study can be calculated.

## 5. Conclusions

LMDCs are important for delivery companies to extend their service in urban areas. Last mile service size is dependent on the needs of specific companies. Moreover, companies can get more satisfaction from customers than other delivery companies if extend the last mile infrastructure for time of e-commerce. The results of this research will help to develop customer satisfaction of parcel delivery service under the last mile concept and offer suggestions for a number of LMDCs to help ease access to customers in dense areas. It should also help with better handling of smart online shopping services in the future. Moreover, it encourages the government sector to provide accessibility of infrastructure in urban areas.

In this paper, the research problem was based on the service coverage area of last mile delivery, which 3PLS considered as a first step to provide more LMDCs and shorter distance service. The author faced the issue of inadequate information from previous research concerning last-mile delivery service in Thailand because most 3PLS come from the private sector. Thus, there are several issues to extend this research that can be suggested for future research direction. First, cost analysis should be assessed in future research for comparing the investment costs and transportation costs when addressing last-mile centers. Second, future research should consider service time in terms of instances of applied distance, between last-mile locations when sending a parcel to a customer at a final destination. Third, this research could be extended by applying the optimization of delivery routing as travel salesman problem (TSP), which applies a set of cities and distances to find the shortest possible route by visiting every city location exactly once and returning to the starting point. Fourth, future research should compare the locations of other 3PLS to study the differences in delivery service area. Moreover, one future research topic involves the period of time to locate LMDCs, which should be studied.

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