Optimization of Last Mile Hub Location Determination for Package Delivery using Facility Location Problem

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Abstract

Technological developments in the world today greatly affect the development of technology-based business models, one of them is E-Commerce or Electronic Commerce. The digital-based trading business is projected to increase by 51.6 percent from 2020. The development of transactions on this online trading platform also affects businesses in the fulfillment or service sector, which includes a series of processes for fulfilling product orders from customers. This process is closely related to the parcel/expedition shipping industry. In an expedition, the process of sending goods from the starting point to the end point is divided into three parts, namely First Mile, Middle Mile, and Last Mile. Last mile delivery is a process carried out by logistics parties to send and deliver packages to recipients. Optimal hub locations can lead to reduced transportation costs as they directly affect the flow of goods. The purpose of determining a suitable location for the hub is to establish an efficient flow of goods delivery connections so that goods can be distributed as quickly as possible to the final recipient of the goods. Therefore, the determination of the Last mile hub becomes very important because it deals directly with the recipient of the goods so that it affects satisfaction with the services of a freight forwarder. In this study, the author uses a case study in an expedition company in Indonesia for the Depok area coverage and uses the Facility Location Problem method to find out the most appropriate location and number of hubs to cover the entire area by considering the coverage area and cost of the selected hub building. The optimization results are able to provide a warehouse choice solution with cheaper warehouse rental costs and cheaper transportation costs in specifications for a larger number of warehouses. As an example of a 10 km coverage scenario, providing 4 warehouses with the furthest delivery point of 9.3 km has a total cost of IDR 6,500,363,150 or 12% lower cost than the existing condition. With a lower furthest point, the distance and time required for parcel delivery is also faster and has the potential to increase customer satisfaction.

Keywords
Facility Location Problem, Last Mile Hub, Logistic, Operation Research, Optimization

1. Introduction
The developments of technology in the world today greatly affect the development of technology-based business models, as well as in Indonesia. One of the businesses that is growing thanks to technology is E-Commerce or Electronic Commerce. E-commerce business in Indonesia is increasing. Digital-based trading business is projected to increase by 51.6 percent from 2020 which reached IDR 266 trillion to IDR 403 trillion in 2021. A report released in October 2020 by Google, Temasek and Bain & Company discussing e-economy 2020 reported that the time used by people to enter online trading platforms or marketplaces during the pandemic increased by 27%. Previously people spent 3.7 hours/day on online trading platforms, but after the pandemic that time increased to 4.7 hours/day.

The development of transactions on this online trading platform also affects businesses in the fulfillment or service sector, which includes a series of processes for fulfilling product orders from customers. This process is closely related to the parcel/expedition shipping industry. Delivery with the type of expedition service is considered faster to arrive because there is a choice of service to arrive in one day. So this service is very popular among the people. Because there are services that refer to speed up and cheaper prices than other services.

In an expedition, the process of sending goods from the starting point to the end point is divided into three parts, namely First Mile, Middle Mile, and Last Mile. First mile delivery is the process by which the sender submits the package to the logistics party. Middle mile is the process of sending goods from the first mile hub to the middle mile hub to be later sorted and sent to the last mile hub based on the destination of the goods sent. While last mile delivery is a process carried out by logistics parties to send and deliver packages to recipients. Each of these processes really requires a hub facility to accommodate the goods to be shipped. According to Carolina & Monica (2016), the location of a hub is considered to be a strategic and long-term decision, especially because of the large investment required to build a hub. Location selection is an important decision element because it affects the success of goods delivery operations (Tu, Chen, Chang, & Lu 2010).

1.1. Objectives

The purpose of this study is to determine the location of the hub by considering the distance as an effort to optimize warehouse rental costs and transportation costs. Optimal hub location can lead to reduced transportation costs because it directly affects the flow of goods. The purpose of determining a suitable location for the hub is to establish an efficient flow of goods delivery connections so that goods can be distributed as quickly as possible to the final recipient of the goods. In this study, the author uses a case study in one of the expedition companies in Indonesia for the Depok area coverage to find out the most appropriate location and number of hubs to cover the entire area.

2. Literature Review

Facility Location Problem or hereafter will be shortened to FLP, is used for transportation problems. Facility location problem asks for the optimal decision on number and location of facilities needed to provide some services to a set of clients. A lot of location problems have to consider both the service costs and the constrained service distance (Weng 2009). There are five types of FLP commonly used for the movement of people and goods, the types of FLP are minisum, set covering, maximal covering, minimax, and obnoxious (Boonmee et al. 2017) In minimum FLP the goal is to have the location of a facility and minimize the total distance between the facility and the point of demand. In the set covering type FLP, the goal is to minimize the cost of building facilities, logistics costs but with the condition that all demand points must be met. There is also maximal covering, namely the problem of reaching as many demand points as possible at a limited cost. In FLP minimax the goal is to minimize the maximum distance from the facility to the request. Finally, the obnoxious type of FLP is aimed at maximizing the distance from the point of request to the point of facility.

In this study, we will discuss determining the most optimal Last Mile Hub location. Last Mile, from supply chain management and transportation planning is the final part of the journey, which consists of the movement of people and goods from the transportation hub to the final destination, (Fincher 2017). Hubs are special facilities that serve as switching, transshipment and sorting points in many-to-many distribution systems, (Alumur and Kara 2007). Last Mile Hub, it can be concluded as an infrastructure that is placed in a strategic location to facilitate the flow of luggage delivery to the end point / recipient of the goods. According (Li et al. 2011), the goal of a suitable logistics center location is to enable products to be used in different markets through optimal connectivity. This allows you to make better use of the available logistics and transportation infrastructure.

3. Method

The research methodology is a problem-solving framework depicted through a flow chart to support the research process that will be made so that research can run more directed and systematically to achieve the research objectives that have been set. The stages of the process carried out in this research can be seen in the following figure.

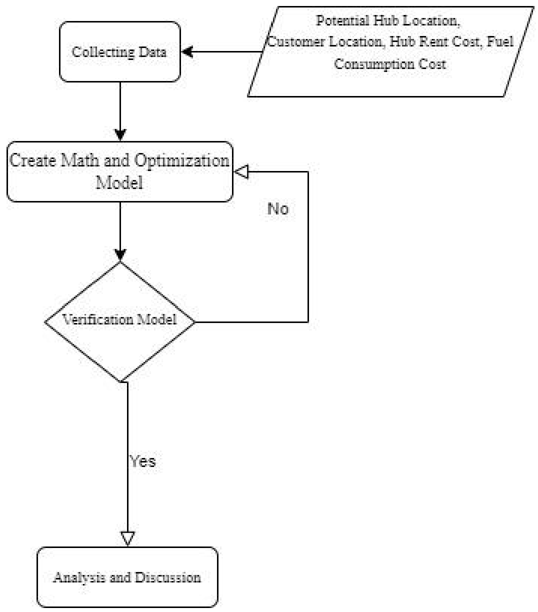

Figure 1. Flow Chart Method

Collecting the data is needed to support solving problems that arise based on the research focus (Figure 1). The data collected includes the location of the Existing Last Mile Hub of PT. XYZ in Depok, last Mile Hub potential location in Depok, customer location, warehouse rental fee, and fuel cost.

At the stage of making a model, formulates a mathematical model as a normative approach to identify and solve problems quantitatively. The model is built by determining the index set of parameters, variables, decision variables, objective functions and problem constraints. After the model is run and the initial results are obtained, the author will validate and verify the optimization model that has been created.

4. Data Collection

In this section, we will explain the data that will be needed in this research and how to process the data. The data collection process is carried out to obtain the variables that will later be needed in data processing for optimization of determining the location of the Last Mile Hub

This data is the location of the Last Mile Hub which is already owned by PT. XYZ in Depok City which is used as a point of receiving goods from Middle Hub before being sent to the end customer. Until the research was carried out, the number of Last Mile Hubs owned by PT. XYZ amounted to 2 Hubs and locations that have the potential to be used as Last Mile Hubs in Depok assuming every sub-district that has not been built Last Mile Hub has 1 Last Mile Hub. Details of potential locations for Last Mile Hub in Depok.

Table 1. Hub Location Data

No	Hub Name	Status	Longitude	Latitude
1	Beji	Potential	106.82373700000000	- 6.37588100000000
2	Bojongsari	Potential	106.74115590000000	- 6.39913080000000
3	Cilodong	Potential	106.85460985966500	- 6.42318881387257

4	Cimanggis	Exist	106.86056800000000	- 6.36651900000000
5	Cinere	Potential	106.78707662529800	- 6.32173380707967
6	Cipayung	Potential	106.88835400000000	- 6.31533100000000
7	Limo	Potential	106.77312210510500	- 6.37051863238359
8	Pancoran Mas	Exist	106.78965746309500	- 6.38392891810595
9	Sawangan	Potential	106.74311488155600	- 6.37375992012956
10	Sukmajaya	Potential	106.85816783162600	- 6.36604612573269
11	Tapos	Potential	106.87948111373500	- 6.38543922460666

This data is the location of the customer domiciled in Depok who will receive the parcel from Last Mile Hub. This data is needed to ensure Last Mile Hub is able to serve deliveries at all customer points. Customer data totals 15,248 location points and some of the data will be shown in the table 2 below.

Table 2. Customer Location Data

No	Buyer Name	Longitude	Latitude
1	Liestia Hany	106.8421249	-6.3620687
2	Dinda Febrianti	106.856514	-6.3969998
3	Keisha Rachel	106.8349609	-6.3861389
4	aldi	106.8722784	-6.356717
5	Nurhana Sri (Ana)	106.8401337	-6.4453964
~	~	~	~
15248	Citra Bunga Edelweiss	106.7913095	-6.3248304

In calculating the distance between the Last Mile Hub locations and Customer Locations, geodetic techniques will be used to measure the distance between the two locations. According to Nichat (2013), in calculating these two distances using the Haversine formula, which is the equation used in navigation to provide the distance of a large circle between two points on the surface of a sphere (Earth) based on longitude and latitude.

$$d = 2r \sin^{-1}\left(\sqrt{\sin^2\left(\frac{\phi_2 - \phi_1}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\psi_2 - \psi_1}{2}\right)}\right)$$

The formula above is then translated into a formula that can be applied in a spreadsheet to become

D= acos(sin(lat1).sin(lat2)+cos(lat1).cos(lat2).cos(long2-long1)).R

Information:
R = Earth's radius of 6371(km)
D = distance (km)

The following is a summary of the results of calculating the distance between the customer's location and the Last Mile Hub location (Table 3)

Table 3. Sample of Calculation Results Distance between customer locations and Last Mile Hub locations

				Beji		Pancoran Mas	
				Longitude 2	Latitude 2	Longitude 2	Latitude 2
No	Buyer Name	Longitude 1	Latitude 1	106.823737	-6.375881	106.789658	-6.383929
1	Liestia Hany	106.8421249	-6.3620687	3.31	km	8.17	km
2	Dinda Febrianti	106.8565140	-6.3969998	5.61	km	9.79	km
3	Keisha Rachel	106.8349609	-6.3861389	2.19	km	6.52	km
4	Aldi	106.8722784	-6.3567170	7.50	km	12.50	km
5	Nurhana Sri (Ana)	106.8401337	-6.4453964	10.32	km	11.47	km
~	~	~	~	~	~	~	~
15248	Citra Bunga Edelweiss	106.7913095	-6.3248304	8.73	km	15.40	km

In the table above, not all data is displayed because the data size is very large so it is not possible to display all the distance data between the hub and the customer.

This data contains details of estimated warehouse rental costs at each location per District. This data is taken from current market conditions to find out the details of the actual rental costs. To get a cost estimate, the researcher took a sample of 5 samples per sub-district location, then the average of the sample results was used as an estimate of the cost per year for existing and potential locations. (Table 4)

Table 4. Warehouse Rental Fee

No.	Last Mile Hub Location	Warehouse Area (m2)	Estimated Rental Fee (Rp/Year)
1	Beji	1000	Rp1,00,.000

2	Bojongsari	1000	Rp850,000
3	Cilodong	1000	Rp490,000
4	Cimanggis	1000	Rp490,000
5	Cinere	1000	Rp1,000,000
6	Cipayung	1000	Rp67,.000
7	Limo	1000	Rp1,000,000
8	Pancoran Mas	1000	Rp1,350,000
9	Sawangan	1000	Rp670,000
10	Sukmajaya	1000	Rp870,000
11	Tapos	1000	Rp1,000,000

Next is the fuel consumption data for the motor which will later be needed to determine the cost of fuel consumption required. According to (Nasri 2015), Vehicles in the motorcycle category require a fuel consumption of 51 km/l. With the price of gasoline at the time of the study at Rp. 7650/l then the price per km of fuel is around Rp. 150/km.

The next stage is to create a mathematical model. Here are the indexes, sets, and parameters to be used in this research optimization (Table 5).

Table 5.Index and Set

Index and Set	Explanation
$i \in H$	Index and set of existing and potential hub coordinates
$j \in C$	Index and set of buyer/customer coordinates

Table 6.Parameter

Parameter	Explanation
D_{ij}	The distance between the Last Mile Hub location to the customer location
C_i	Warehouse Rental Fee for Last Mile Hub
C_{ij}	Transportation costs for package delivery from Last Mile Hub to Customer

As previously explained, the objective function of optimization in this study is to reach 100% of customer locations by minimizing costs. By using the index, set, and parameters in the previous table, decision variables, objective functions, and constraints can be formulated (Table 6)

Table 6. Decision Variable

Decision Variable	Explanation
$S_j \in \{0,1\}$	1 if hub j is selected. 0 if hub j is not selected

Objective Function :

$$\text{Min } Z = \sum I \in H, j \in C S_j * C_{ij} + S_j * C_i$$

Limitation :

- $\sum j, S_j \geq 1$
- $S_j \in \{0,1\} \forall \ i \in H$

The objective function for this optimization model is to minimize the costs required for the operation of Last Mile Hub.

Data processing is a way to convert raw data into data that is ready to be entered. This process is very important to make the optimization process easier and smoother. Data processing involves different steps. The first step is to save the data. After getting the desired data, the authors clean the data using Microsoft Excel, which will then be processed using Open Solver. Data organization is used so that data can be processed easily and quickly.

The second step is to determine the maximum distance limit. The principle is to ensure that every customer can be served by Last Mile Hub. In this study, it is divided into three maximum distance limits. The maximum distance limit in this study used a distance of 6 km, 10 km, 14 km, and 20 km. This distance is obtained assuming one courier sends 125 packages per day assuming the motor speed is 30 km/hour and the distance between customer points is varied at 300 m, 500 m, 700 m, and 1 km.

The third stage is to perform optimization. The optimization this time is to reach 100% of customers at the lowest possible cost. The purpose of this optimization result is to get the minimum cost.

5. Results and Discussion

At this stage, we will discuss the optimization results which are the core of the entire research report which contains analysis of various scenarios carried out to answer the research objectives and provide recommendations based on the results of the analysis.

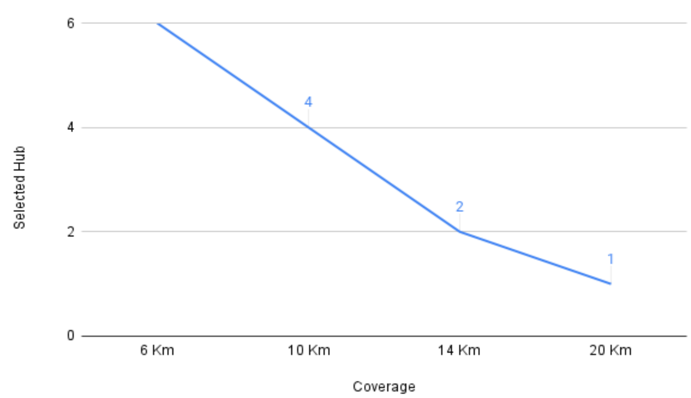

Figure 2. Selected Hub vs Coverage

From the figure 2, it can be seen, the wider the reach of Last Mile Hub, the fewer the number of warehouses to choose from. This is because the wider the reach of a warehouse, the wider the number of customer points that can be reached by the Hub so that the number of Hubs needed is also less.

It can be seen that if the scenario of the Last Mile Hub's coverage area is 6 km, then 6 warehouses are needed to support operations. In the scenario that the Last Mile Hub's coverage area is 10 km, 4 warehouses are needed to support operations. In the scenario that the Last Mile Hub's coverage area is 14 km, 2 warehouses are needed to support operations. The scenario of the Last Mile Hub coverage area is 20 km, so 1 warehouse is needed to support operations From the figure 3, it can be seen that the wider the reach of Last Mile Hub, the less costs needed to rent a warehouse.

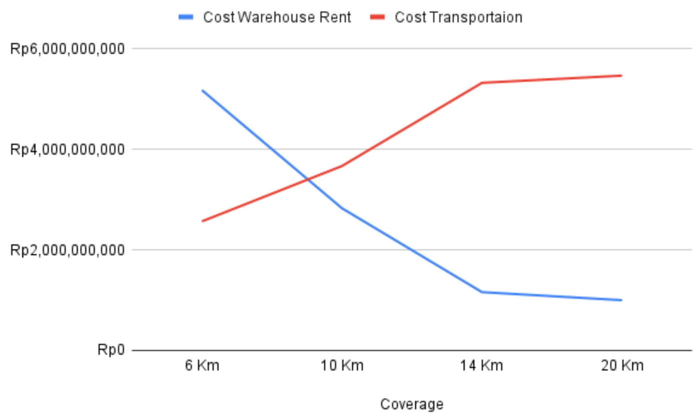

Figure 3. Selected Hub vs Rent Cost & Fuel Cost

This is influenced by the results of the previous analysis, namely the wider the range of Last Mile (Figure 3), the higher the number of customers that can be served by one hub and the smaller the number of Hubs needed. It can be seen that if the scenario of the Last Mile Hub's coverage area is 6 km, then 6 warehouses are needed to support operations and require a warehouse rental fee of Rp. 5,180,000,000. The scenario of the Last Mile Hub's coverage area of 10 km, it takes 4 warehouses to support operations and requires a warehouse rental fee of Rp.2.830,000,000. The scenario of the Last Mile Hub's coverage area of 14 km requires 2 warehouses to support operations and requires a warehouse rental fee of IDR 1,160,000,000. In the scenario that the Last Mile Hub's coverage area is 20 km, it takes 1 warehouse to support operations and requires a warehouse rental fee of IDR 1,000,000,000.

From the same graph above, it can also be seen that the wider the reach of Last Mile Hub, the higher the costs required for transportation costs. This is influenced by the wider range of Last Mile, the longer the distance needed by the courier to deliver the package. It can be seen if the scenario of the Last Mile Hub's coverage area of 6 km has the furthest drop off point of 5.9 km with a total transportation cost of Rp. 2,568,356,764. The scenario of the Last Mile Hub coverage area of 10 km has the furthest drop off point of 9.3 km with a total transportation cost of Rp. 3,670,363,150. The scenario of the Last Mile Hub coverage area of 14 km has the furthest drop off point of 12.5 km with a total transportation cost of Rp. 5,325,774,161. The scenario of the Last Mile Hub coverage area of 20 km has the furthest drop off point of 18.5 km with a total transportation cost of Rp. 5,468,906,298.

Then in this analysis, we will compare the conditions after optimization with variations in the range of the Last Mile Hub and existing conditions in the following table 8.

Table 8. Comparison of Existing Conditions and Optimization Results

Condition/Scenario	Existing Condition	Coverage 6 km	Coverage 10 km	Coverage 14 km	Coverage 20 km
Selected Warehouse	2	6	4	2	1
Rent Cost	Rp 1,840,000,000	Rp 5,180,000,000	Rp 2,830,000,000	Rp 1,160,000,000	Rp 1,000,000,000
Fuel Cost	Rp 5,543,536,152	Rp 2,568,356,764	Rp 3,670,363,150	Rp 5,325,774,161	Rp 5,468,9062,98
Total Cost	Rp 7,383,536,152	Rp 7,748,356,764	Rp 6,500,363,150	Rp 6,485,774,161	Rp 6,468,906,298

Farthest Point	18.5 km	5.9 km	9.3 km	12.5 km	18.5 km

From the table above, it can be seen that the optimization results are able to provide a warehouse choice solution with cheaper warehouse rental costs and cheaper transportation costs in specifications for a larger number of warehouses. As an example of a 10 km coverage scenario, providing 4 warehouses with the furthest delivery point of 9.3 km has a total cost of IDR 6,500,363,150 or 12% lower cost than the existing condition. With a lower furthest point, the distance and time required for parcel delivery is also faster and has the potential to increase customer satisfaction.

6. Conclusion and Future Research

Optimal hub location can lead to reduced transportation costs because it directly affects the flow of goods. The purpose of determining a suitable location for the hub is to establish an efficient flow of goods delivery connections so that goods can be distributed as quickly as possible to the final recipient of the goods. Literature studies were also conducted to examine the Last Mile Hub, Optimization Model, Facility Location Problem, and how to verify and validate the optimization model. From the results of this study, it can be concluded that the optimization model is able to determine the location of the Last Mile Hub with the lowest warehouse and transportation rental costs compared to existing conditions. Compared to other studies, this study uses transportation costs as one of the variables to determine and consider the location of the selected hub.

Based on the results of the study, the following are some suggestions that can be made in further research, including further research to provide a function to limit warehouse capacity, take into account and optimize the number of couriers, consider couriers to have their own routes and not assume one-way for optimizing advanced transportation costs and adding recommended courier routes for further optimization of transportation costs

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