ISBN: 978-981-18-5852-9
WCSE 2022 Spring Event: 2022 9th International Conference on Industrial Engineering and Applications
doi: 10.18178/wcse.2022.04.049

Identifying Warehouse Location: A Case Study of an e-Commerce Firm

Piya Charoendee [1+] Detcharat Sumrit [2] Assadej Vanichchinchai [3] Suwat Janyapoon[4]

[1-3] Faculty of Engineering, Mahidol University, Nakhon Pathom, Thailand

[4] College of Logistics and Supply Chain, Sripatum University, Bangkok, Thailand

Abstract. The purpose of this study is to identify a central warehouse location of an e-commerce firm in Thailand by considering the lowest parcel transportation cost. Shipment and location data of all warehouse spokes were used for calculation with two methods: center of gravity and load distance. It was found that the location identified with load distance method had the lowest transportation cost, 17.86% lower than that of existing location.

Keywords: warehouse location, center of gravity, load distance

1. Introduction

Finding a warehouse location is an important aspect of optimizing a logistics system [1]. An appropriate location is a guarantee of creating successful supply chain in terms of both lower costs and greater profits. Warehouse locations in a supply chain network determines the efficiency and speed of the supply chain [2]. Therefore, choosing the location is very important in the business sector. If it is located in an unfavorable area, it will impact the costs in the long run. Changing the location of a warehouse is something that needs to be carefully examined and planned.

Electronic commerce or e-commerce transactions, are the sale or purchase of parcels or services, conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders [3]. Current trends show a worldwide increase in e-commerce sales. “In 2020, retail e-commerce sales worldwide amounted to 4.28 trillion US dollars and e-retail revenues are projected to grow to 5.4 trillion US dollars in 2022” [4].

In Thailand, there is a large increase in e-commerce sales. The survey of Electronic Transactions Development Agency in Thailand 2019 showed that the value of e-commerce in 2018 amounted to USD 124,1675.98 million, with a growth rate of 36.36 percent from the previous year (compared to the value in 2017 which was USD 91,056.63 million) [5].

For instance, a case study of an e-commerce firm located Thailand shows how e-commerce is popular and continuously growing in Southeast Asia. It operates in several countries including Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. The firm hosts various local and international online merchants and brands. The service offers categories such as electronics, home goods, children's toys, fashion items, sporting goods, etc. The revenue from the operation has been increasing, and the number of items delivered has increased 125 times in 5 years.

As an emerging digital society, there is a high opportunity to continue value growth in e-commerce and facilitate economic growth within Thailand. Thus, warehouse location is very important because it is related to the costs of transportation for shipping parcels and can affect other aspects of the logistics system. Therefore, optimal geographical positioning in Thailand for locating warehouses for e-commerce can be an alternative strategy for increasing the efficiency of the logistics system in terms of reducing transportation cost.

[+] Corresponding author. Tel.: + 668 2563 5000
E-mail address: p.charoendee@gmail.com.

The purposes of this study were to identify an optimal warehouse location in Thailand using an e-commerce firm as a case study by considering the lowest total parcel shipping transportation cost and distance, and to compare the reduction of transportation cost between the optimal locations which was calculated by two methodologies which were the Center of Gravity method and the Load-distance method (LD).

2. Literature Review

Considering literature related to identifying warehouse location, it was found that there were different methods used depending on the purposes and location of the studies. Multiple-criteria decision-making (MCDM) methods and examination of several criteria were used as a solution for a supermarket chain located in Turkey [6]. Fuzzy Analytic Hierarchy Process (FAHP) had been used to select warehouse locations for a global supply chain through a case study in Iran [1] and had been used as a decision support framework for selecting a location and creating a disaster relief network design in Indonesia [7]. Examining the location choices of warehousing facilities was studied to understand how and why warehouses have changed location over time from central urban areas in Los Angeles, CA [8]. Heat Maps: Relative Advantage, Task-Technology Fit, and Decision-Making Performance were used for determining the best site for a new retail store or locating an ideal neighbourhood for a future city park in the USA [9]. Euclidean distance linearization was used to search for an optimal mathematical program for the warehouse location problem [10]. Distance, tapering freight rate, and population were taken into consideration for finding a warehouse location in Thailand [11]. A study in the case of an online retailer used a Center of Gravity (COG) approach and mixed integer linear programming to optimize the distribution centre location decision for single and double hub scenarios in UK [12].

As a characteristic of an e-commerce firm is related to parcel delivering, the transportation cost is significantly related to the total operating cost of the distribution center of a warehouse. The component of transportation cost is a fixed cost and a variable cost. The variable cost depends on distance of parcel delivery. Moreover, the volume of demand of each spoke or distribution center refers to the transportation cost. Therefore, this study used two methodologies, the Center of Gravity method (COG) and the Load-distance method (LD) to identify an optimal location in Thailand to locate a warehouse for a case study of an e-commerce firm, using quantitative data and considering the lowest total parcel shipping transportation cost and distance.

3. Theoretical Background

3.1 Center of Gravity Method (COG)

The COG is a common method of determining available warehouses to minimize the cost of transportation. COG considers of the cost of transportation, which varies with the quantity of parcels delivered, or the demand of parcels and the destination. This study selected COG to search for an optimal location by considering the workload and distance of existing distribution centers through a case study of an e-commerce firm expressed in the following equations (1) and (2):

$$C_x = \sum X_i V_i / \sum V_i \tag{1}$$

$$C_y = \sum Y_i V_i / \sum V_i \tag{2}$$

The variables of C_x and C_y are coordinate points of optimal location by COG, C_x is a point of latitude and C_y is a point of longitude. X_i is a point of latitude and Y_i is a point of longitude for existing distribution centers, location i, i = 1,2,…,76. V_i is the average of quantity for delivering parcels or demand of parcels on existing distribution centers, location i, i = 1,2,…,76 as following Table 1:

Table 1: Variables of Center of Gravity Method (COG)

Variables	Descriptions
C_x	Latitude of an optimal existing distribution center.

C_y	Longitude of an optimal existing distribution center.
X_i	Latitude of the existing distribution centers.
Y_i	Longitude of the existing distribution centers.
V_i	Average of quantity of delivering parcels or demand of parcels on the existing distribution centers.

3.2 Load-Distance Method (LD)

The LD is a method of selecting an optimal location out of several proposed locations by calculating the distance of each location from the materials or market. Then multiply those distances by quantity of delivering parcels or demand of parcels expressed in the following equation (3):

$$LD_{ij} = \sum V_i D_j \tag{3}$$

The above eq.(3), LD_{ij} is the total quantity of delivering parcels or demand of parcels on existing distribution centers, location i, i = 1,2,…, 76 multiple by distance of proposed location j, j = 1,2,…, 24. However, the distance can be measured by using the principle of measuring in a straight line as shown in Figure 1:

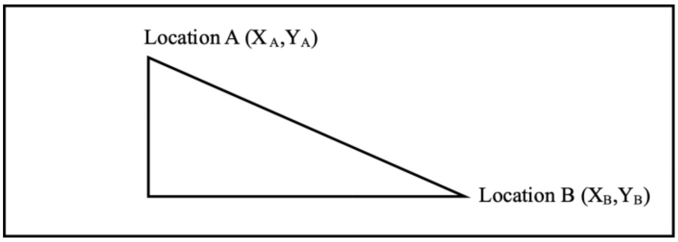

Fig. 1: A measuring in a straight line.

Triangles can be used to measure distant objects through the Pythagorean theorem as shown in the following equation (4):

$$dAB = \sqrt{((X_A-X_B)^2+(Y_j-Y_B)^2)} \tag{4}$$

Formulating the LD equation by using the Pythagorean theorem for the distance shown in the following equation (5):

$$LD_i = \Sigma V_i \left[\sqrt{((X_A-X_B)^2+(Y_A-Y_B)^2)}\right] \tag{5}$$

The variable of V_i is the quantity of delivering parcels or demand of parcels on existing distribution centers, location i, i = 1,2,…,76. X_A is the point of latitude of the proposed location and X_B is the point of latitude of the existing distribution center. Y_A is the point of the proposed location and Y_B is the point of longitude of the existing distribution center as following Table 2:

Table 2: Variables of Load-Distance Method (LD)

Variables	Descriptions
XA	Latitude of proposed location in Thailand.
YA	Longitude of proposed location in Thailand.
XB	Latitude of the existing distribution centers.
YB	Longitude of the existing distribution centers.
Vi	Average of quantity of delivering parcels or demand of parcels on the existing distribution centers.

3.3 The Case Study of e-Commerce Firm

The case study of an e-commerce firm finds that the firm has 1 main warehouse or hub in Samutprakarn province, which is one of the central provinces in Thailand. That hub operates picking, packing, and delivers to 76 sub-regional distribution centers or spokes. The average quantity of parcels delivered to all spokes was 219,996 pieces per month and the total transportation cost was 562,271.98 Bath.

4. Concept and Methodology for This Study

This retrospective study was conducted from September 2020 – August 2021. Two methodologies were used, COG and LD. COG was used for identifying an optimal location by considering the workload and distance of existing distribution centers, and LD was used for identifying an optimal location where the workload and distance was the lowest through simulation. Then a comparison of transportation cost reduction between the optimal locations from two methodologies was expressed as the following in Figure 2:

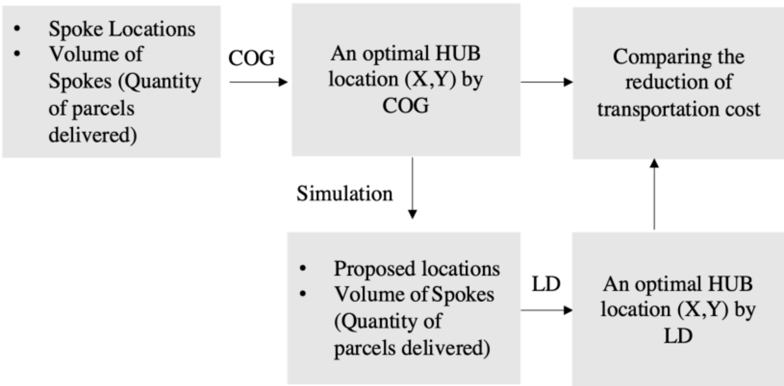

Fig. 2: The conceptual Framework of identifying warehouse location: A case study of an e-commerce firm.

5. The Results

The result of the COG method showed that by computing the 76 locations of existing distribution centers in Microsoft Excel with the eq. (1) and (2), showed the coordinate of COG (X,Y) was at a latitude of 13.85485 and a longitude of 100.66039 which is located in the Tharang subdistrict, Bang Khen district, Bangkok, Thailand as seen in the following Table 3:

Table 3: The Results of Computing COG

No.	Vi (1)	Spoke location (X,Y)		X.V (4)=(1)*(2)	Y.V (5)=(1)*(3)
		X_i (2)	Y_i (3)		
1	1,846	14.49902	100.97003	26,765.19	186,390.68
2	983	13.53067	99.72710	13,300.65	98,031.74
3	3,623	14.29795	100.65518	51,801.47	364,673.72
4	3,101	13.66122	100.62114	42,363.45	312,026.15
5	5,485	13.90952	100.41839	76,293.71	550,794.86
6	4,705	13.71108	100.66666	64,510.62	473,636.64
7	4,272	13.84855	100.63392	59,161.01	429,908.11
8	3,718	13.75997	100.63980	51,159.57	374,178.76
9	6,980	13.64453	100.42988	95,238.82	701,000.56
10	2,754	13.53784	100.68773	37,283.22	277,294.00
11	866	14.95879	103.06298	12,954.31	89,252.54
12	3,508	13.37860	101.02982	46,932.13	354,412.61
13	1,872	13.65306	101.04489	25,558.52	189,156.03

No.	Vi (1)	Spoke location (X,Y)		X.V (4)=(1)*(2)	Y.V (5)=(1)*(3)
		X_i (2)	Y_i (3)		
14	1,599	19.89805	99.81184	31,816.98	159,599.13
15	609	12.83590	99.93220	7,817.06	60,858.71
16	960	10.51069	99.16426	10,090.26	95,197.69
17	3,658	18.77061	99.04229	68,662.90	362,296.69
18	3,251	18.83278	98.97677	61,225.37	321,773.47
19	1,293	12.65175	102.03917	16,358.72	131,936.64
20	2,926	13.83317	100.56438	40,475.84	294,251.36
21	3,876	13.77957	100.60089	53,409.61	389,929.04
22	2,923	13.94324	100.60963	40,756.10	294,081.95
23	2,189	13.81909	100.53519	30,250.00	220,071.54
24	3,306	7.01829	100.43048	23,202.47	332,023.18
25	1,171	12.50164	99.90801	14,639.42	116,992.28
26	4,753	7.86128	98.36680	37,364.67	467,537.39
27	8,153	13.76250	100.40146	112,205.66	818,573.10
28	1,365	13.97716	101.82530	19,078.82	138,991.54
29	3,599	16.45916	102.85404	59,236.51	370,171.69
30	846	12.78993	101.64971	10,820.28	85,995.65
31	4,530	14.09335	100.69023	63,842.85	456,126.73
32	1,469	13.96804	100.00358	20,519.05	146,905.26
33	2,470	13.73584	100.72067	33,927.53	248,780.06
34	4,381	13.11172	100.93723	57,442.46	442,206.00
35	1,683	14.78491	100.68352	24,883.00	169,450.36
36	1,739	18.26462	99.46394	31,762.17	172,967.79
37	1,886	18.56302	99.04196	35,009.85	186,793.13
38	1,062	16.17447	103.29535	17,177.29	109,699.66
39	5,046	13.88461	100.73312	70,061.72	508,299.31
40	3,629	14.06086	100.52436	51,026.87	364,802.91
41	4,389	14.99626	102.13059	65,818.59	448,251.16
42	1,280	15.67947	100.13312	20,069.72	128,170.39
43	3,043	13.83165	100.06670	42,089.70	304,502.97
44	980	14.21734	101.19416	13,932.99	99,170.28
45	1,378	17.85287	102.75044	24,601.26	141,590.11
46	2,882	13.41078	101.11190	38,649.87	291,404.50
47	1,137	14.67694	101.40229	16,687.68	115,294.40
48	498	13.06796	99.94612	6,507.84	49,773.17
49	2,664	12.94656	101.15958	34,489.63	269,489.13
50	647	16.42156	101.15646	10,624.75	65,448.23
51	1,725	16.74741	100.25856	28,889.29	172,946.02
52	2,913	13.93315	100.51912	40,587.27	292,812.18
53	1,545	13.97301	101.50324	21,588.30	156,822.51
54	883	14.69961	102.01866	12,979.75	90,082.48
55	945	13.70096	99.85904	12,947.41	94,366.79
56	4,726	13.97739	100.62466	66,057.15	475,552.14
57	4,855	12.90696	100.94407	62,663.28	490,083.46
58	3,553	12.70536	101.28092	45,142.15	359,851.10

No.	Vi (1)	Spoke location (X,Y)		X.V (4)=(1)*(2)	Y.V (5)=(1)*(3)
		X_i (2)	Y_i (3)		
59	3,076	13.63438	100.52748	41,939.35	309,222.53
60	4,437	13.68601	100.54509	60,724.82	446,118.54
61	3,794	13.87412	100.49290	52,638.41	381,270.06
62	6,064	13.58811	100.25619	82,398.31	607,953.56
63	1,321	7.13473	100.57042	9,424.98	132,853.52
64	5,605	13.71497	100.57506	76,872.41	563,723.19
65	3,841	13.86909	100.64757	53,271.16	386,587.30
66	3,061	13.61367	100.64161	41,671.44	308,063.97
67	988	13.39834	99.98673	13,237.56	98,786.89
68	3,677	13.69775	100.48839	50,366.61	369,495.80
69	3,725	13.70397	100.28437	51,047.29	373,559.28
70	2,184	15.16161	104.85535	33,112.96	229,004.08
71	2,299	9.11688	99.29226	20,959.71	228,272.91
72	2,321	17.34994	102.82330	40,269.20	238,652.88
73	2,410	12.73457	100.94083	30,690.32	243,267.40
74	4,471	13.78467	100.56107	61,631.26	449,608.53
75	6,128	13.63861	100.70402	83,577.37	617,114.26
76	2,466	13.57084	100.83078	33,465.68	248,648.71
Sum	219,996			3,048,011.55	22,144,883.06
C_x = Sum (4) / Sum (1) = 13.85485					
C_y = Sum (5) / Sum (1) = 100.66039					
HUB location (X,Y) = 13.85485, 100.66039					

The result of the LD method computed 24 proposed locations around the existing distribution center or spoke of Tharang subdistrict to find an optimal location. Those were computed with the 76 locations in Microsoft Excel with the equation (5). It found that the lowest value of LD was equal to 36,427,032.7 pieces and located at a latitude of 13.778 and a longitude of 100.567. That was located in Din Daeng subdistrict, Din Daeng district, Bangkok, Thailand. However, considering the transportation cost, the lowest was at a latitude of 13.782 and a longitude of 100.545, which is in Samsen Nai subdistrict, Phaya Thai district, Bangkok, Thailand. The optimal location of LD is shown in the following Table 4:

Table 4: The Results of Computing LD

No.	Latitude (X)	Longitude (Y)	Load Distance (pcs*km)	Transportation cost (Baht)
1	13.871	100.580	36,777,926	477,515
2	13.811	100.612	37,014,533	477,695
3	13.921	100.654	37,426,031	501,649
4	13.868	100.606	36,711,900	477,776
5	13.839	100.700	37,928,132	508,379
6	13.866	100.650	36,965,465	484,762
7	13.808	100.650	36,933,160	478,827
8	13.821	100.677	37,236,731	490,447
9	13.826	100.565	36,564,001	467,335
10	13.925	100.593	37,778,991	508,250
11	13.912	100.506	38,006,341	509,261
12	13.769	100.577	36,910,121	472,273
13	13.850	100.509	37,073,565	479,591

No.	Latitude (X)	Longitude (Y)	Load Distance (pcs*km)	Transportation cost (Baht)
14	13.778	100.567	36,427,033	463,430
15	14.012	100.528	38,884,582	544,122
16	13.782	100.545	36,437,969	461,839
17	13.820	100.529	36,711,061	467,175
18	13.756	100.660	37,015,935	482,264
19	13.779	100.609	36,766,709	470,046
20	13.987	100.632	38,167,741	525,482
21	13.804	100.723	38,233,704	522,783
22	13.761	100.688	37,408,316	496,035
23	13.869	100.885	40,149,339	597,632
24	13.972	100.774	39,326,970	570,368

The total transportation cost of the current warehouse location of the e-commerce firm was 562,271.98 Baht. The comparison of transportation cost reduction between the location of COG and the location of LD, shows that the location of LD, in the Samsen Nai subdistrict, had a higher reduction of 100,433 Baht, or 17.86 percent of the current transportation cost, while the cost reduction of the location of COG, Tharang subdistrict was 67,963 Baht, or 12.09 percent of current transportation cost as seen in the following Table 5:

Table 5: The Results of Comparison of Transportation Cost Reduction

Location	Transportation cost (Baht)	Cost reduction	%Cost reduction
Bang Pla subdistrict (Current HUB)	562,271.98	-	-
Tharang subdistrict (COG Point)	494,309	-67,963	-12.09%
Samsen Nai subdistrict (LD Point)	461,839	-100,433	-17.86%

6. Conclusion and Policy Implications

Parcel delivering is one of important processes related to the logistics system, and the transportation cost is significantly related to the total operating cost of the distribution center of warehouses for e-commerce companies. This study used two methodologies, the Center of Gravity method (COG) and the Load-distance method (LD) to identify an optimal location in Thailand to place a warehouse by using a case study of an e-commerce firm, using quantitative data and considering the lowest total parcel shipping transportation cost and distance.

This study was a selection of optimal geographical positioning in Thailand to locate a warehouse the e-commerce firm by combining the COG and LD methods to identify an optimal location where total transportation cost for shipping parcels and distance was the lowest. This was a retrospective study, computing the secondary data from September 2020 – August 2021.

The result of the COG showed that the coordinate where the cost of transportation by considering workload and location of existing distribution center was minimized was in Tharang subdistrict, Bang Khen district, Bangkok, Thailand. The LD result showed that the coordinate where the workload and distance was the lowest was in Samsen Nai subdistrict, Phaya Thai district, Bangkok, Thailand. However, the result of transportation cost reduction between the two optimal locations, found that Samsen Nai subdistrict had a higher reduction. Samsen Nai subdistrict, Phaya Thai district, Bangkok then, was the optimal geographical positioning in Thailand for locating the warehouse for the e-commerce firm from the case study in terms of increasing the efficiency of the logistics system by reducing shipping costs.

This study can be an alternative strategy for e-commerce firms to increase the efficiency of their logistics systems in terms of reducing transportation cost.

7. Limitation

This study only considered the cost factor. There were other factors that should be taken into further consideration such as facility accessibility, location availability, labor wage rates, size of warehouse, product distributing strategies, etc.

8. Reference

[1] Demirel, T., Demirel, N. and Kahraman, C., 2010. Multi-criteria warehouse location selection using Choquet integral. Expert Systems with Applications, 37(5), pp.3943-3952.

[2] Singh, R., Chaudhary, N. and Saxena, N., 2018. Selection of warehouse location for a global supply chain: A case study. IIMB Management Review, 30(4), pp.343-356.

[3] Directorate, O., 2022. OECD Glossary of Statistical Terms - Electronic commerce Definition. [online] Stats.oecd.org. Available at: <https://stats.oecd.org/glossary/detail.asp?ID=4721> [Accessed 9 October 2021].

[4] Statista. 2022. Global retail e-commerce market size 2014-2023 | Statista. [online] Available at: <https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/> [Accessed 9 October 2021].

[5] Etda.or.th. 2022. Value of e-Commerce Survey in Thailand 2019. [online] Available at: <https://www.etda.or.th/th/Useful-Resource/publications/Value-of-e-Commerce-Survey-in-Thailand-2019_EN.aspx> [Accessed 9 October 2021].

[6] Emeç, Ş. and Akkaya, G., 2020. A stochastic multi-criteria decision-making analysis for a warehouse location selection problem: a case study. International Journal of Research – Granthaalayah, 7(12), pp.133-143.

[7] Demirel, T., Demirel, N. and Kahraman, C., 2010. Multi-criteria warehouse location selection using Choquet integral. Expert Systems with Applications, 37(5), pp.3943-3952.

[8] Kang, S., 2020. Warehouse location choice: A case study in Los Angeles, CA. Journal of Transport Geography, 88, p.102297.

[9] Erskine, M., Khojah, M. and McDaniel, A., 2019. Location selection using heat maps: Relative advantage, task-technology fit, and decision-making performance. Computers in Human Behavior, 101, pp.151-162.

[10] You, M., Xiao, Y., Zhang, S., Yang, P. and Zhou, S., 2019. Optimal mathematical programming for the warehouse location problem with Euclidean distance linearization. Computers & Industrial Engineering, 136, pp.70-79.

[11] Vanichchinchai, A. and Apirakkhit, S., 2018. An identification of warehouse location in Thailand. Asia Pacific Journal of Marketing and Logistics, 30(3), pp.749-758.

[12] Ghadge, A., Yang, Q., Caldwell, N., König, C. and Tiwari, M., 2016. Facility location for a closed-loop distribution network: a hybrid approach. International Journal of Retail & Distribution Management, 44(9), pp.884-902.