P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : https://tci-thaijo.org/index.php/SciTechAsia
Science & Technology Asia
Vol.29 No.4 October - December 2024
Page: [224-234]
Original research article

Proposing a Location of the New Distribution Center: A Garment Case Study in Thailand

Prapaporn Kaewnum, Chumpol Monthatipkul*

Graduate School of Management and Innovation, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand

Received 12 April 2020; Received in revised form 12 December 2020
Accepted 21 November 2024; Available online 27 December 2024

ABSTRACT

This paper applied the principle of the Load Distance technique in order to find a location of a new distribution center. A case study of a garment company in Thailand was conducted. All company policies and constraints were organized and taken into account when considering a location for the new distribution center. A mathematical model was formulated and the location of the new distribution center was determined based on the cost and related company constraints. Sensitivity analysis was then performed to study the robustness of the proposed solution. Due to price and availability of land, the model was rerun to determine a new location for the new distribution center. Finally, the final suggestion for the top management of the case study was made.

Keywords: Distribution center; Location selection problem; Multiple products; Mathematical model; Sensitivity analysis

1. Introduction

Facility location selection is a problem regarding determination of suitable facility sites in order to serve demand. The most appropriate location must be obtained in order to better the efficiency of physical flows and optimize some key objective functions. So far, methods to be used in the selection of facility locations have received much attention from the community. One useful review in this field can be seen in Gergin RE and Peker I [1]. The authors investigate methods and success factors, which have been used to determine warehouse locations by many researchers. In general, these methods can be categorized

***Corresponding author:** ratphadu@engr.tu.ac.th **doi:** 10.14456/scitechasia.2024.83

into the following groups: multi-criteria decision making, fuzzy logic, statistical analysis, linear and mathematical programming, heuristic and meta-heuristic methods, and decision support systems. This paper proposes a new method to determine a suitable site of a new distribution center for a particular case study in Bangkok. The proposed method is mainly based on mathematical programming.

The proposed mathematical model in this paper can be considered as an extended version of the model in Monthatipkul [2]. The author has formulated a nonlinear mathematical model to find a location for a second warehouse for a paper distributor in Bangkok, Thailand. The main goal is to decrease the total transportation cost in a long run. After numerical runs with the actual data of the case study, the useful suggestions for the top management are provided. The model of Monthatipkul [2] can be used for determining a warehouse location when supplying a single type of product, and only product weight is considered. This paper contributes a model which considers multiple products and product volume.

The case study in this research is a famous brand in the garment business in Thailand. It receives multiple types of products from many manufacturers and sells them to end users. The founder is Thai and it has been established since 1996. In 2013, its sales were 2 billion Baht through domestic sales and export. However, the sales have reached 7 billion Baht in 2019. The company has a very high growth. The top management has projected that the company growth can reach approximately 30% within the next five years. Presently, the company sells more than 10,000 types of garment products. They are divided into three main categories, namely, Brand Boy (BB), Brand Young (BY), and Brand Kid (BK) and E-Commerce. The head office of the case study is located in the middle of Bangkok, on Rama 9 Road. It also operates one distribution center, which is on the east side of Bangkok, at King Kaew Road (close to Suvarnabhumi International Airport). The distribution center has an area of approximately 10,000 square meters. Currently, the company has deployed four key business strategies: excellent inventory management, high order fulfillment performance, productive operations, and high transportation performance.

Daily, the company transports its products to point of sales, mainly located at department stores, shopping malls, plazas, shops, etc., around the country (mainly in Bangkok and its perimeter). It utilizes a POS system, which transfers data to a SAP system at the head office. Product picking and distributing are planned and operated by using a WMS system. However, since the company has very high growth, it has been facing some major difficulties, for instance, storage errors, stock counting errors, picking errors, etc. Lack of space can be identified to be the main cause of these problems. Thus, for the management team, opening a new distribution center is a main concern of the case study. This research is therefore to provide a suggestion: where should the new distribution center be opened?

To simplify the analysis without loss of generality, the following assumptions are made.

The latitude and longitude system is used for location identification. Note that the numbers are modified due to confidentiality issues.

This research uses displacement distances (Euclidean distances) rather than actual distances because the determination of actual distances between unknown points is too cumbersome. The calculation of displacement distances utilizes the Pythagorean theorem.

The Load Distance technique is used as a core mechanism to estimate a location of the new distribution center.

The weight numbers are obtained by considering the shipment frequency, forecasted overall demand, product weight and volume, transportation capacity, and fuel consumption rates.

The forecasted overall demand is projected by the marketing department. The historical data, some marketing factors, and company growth are used.

The old distribution center is still running. Each demand point must be served by only one of the two distribution centers (the old or the new distribution center). It cannot be assigned to both distribution centers simultaneously.

The remainder of this article is organized as follows. Section 2 presents a literature review. Section 3 formulates a mathematical model for determining the location for the new distribution center. A numerical example is provided in Section 4. Section 5 shows an application of the model to the case study. Section 6 concludes a summary.

2. Literature Review

This article belongs to the continuous facility location problem, which is concerned with determining suitable locations of the firm's facilities in the plain space in order to serve customer demand effectively. As stated in Monthatipkul [2], the continuous facility location problem can be defined as: Given n-dimensional points (vertices) $P_1, P_2, ..., P_p$ in $\mathbb{R}^n$ and positive multipliers (weights) $\omega_1, \omega_2, ..., \omega_p \in \mathbb{R}^+$, find a point P^* that minimizes $\sum_p \omega_p \|P^* - P_p\|$denotes the Euclidean norm of $P^* - P_p$.

The early studies in this area are the Fermat Problem, the Weber Problem [3], and Weiszfeld's Algorithm [4]. The authors studied classical location problems by determining a suitable location of point which could minimize the positive weighted displacement distances among p given vertices in the plain area. A more in-depth study with a $p > 3$ version was further analyzed by Kulin and Kuenne [5]. The authors proposed an efficient algorithm to the generalized Weber Problem in spatial economics so as to minimize the transport cost. Based on an empirical basis, the authors solved 15 problems involving 3 to 24 points. There have also been many researchers in the field who have developed solution methods and contributed their work to the community [6-8].

A study covering both positive ($\omega_p > 0$) and negative weights ($\omega_p < 0$) was presented by Tellier (as cited in [9]) and further investigated by Chen et al [10]. Korte and Vygen [11] claimed that the Fermat-Weber Problem was a weighted median problem if all concerned points were collinear. It was a foundational concept of the Center of Gravity method. Modifying Weiszfeld's algorithm to cover a general cost objective function and some specified conditions was investigated by Vardi and Zhang [12], and Szegedy [13]. Some points were fixed to a particular point and the remaining points were used to find a new solution point. However, Weiszfeld's algorithm takes a long time [14].

Recently, solution methods for variant facility location problems have been studied by many researchers [15, 16]. Dhanashekar and Kumar [17] proposed a model for selecting optimal warehouse locations based on uncertain customers and uncertain demands. Their papers showed a simulation which could propose an optimal number of warehouse locations. The number of warehouses was not constant depending on related uncertainties. Chau TDL et al. [18] also determined an optimal warehouse location in a multi-product multi-period distribution network. The authors used a mathematical model to obtain an optimal location of a new external warehouse, its capacity, and product-facility-market allocation, so as to minimize the total transportation and warehousing costs. A real-world large-scale example from industry was used as a case study and finally a sensitivity analysis was conducted based on three key parameters: demand, transportation cost, and warehousing cost. Monthatipkul [2] proposed a mathematical model to determine an appropriate location for the second warehouse for a case study in Thailand. The author considered the firm's requirements and conditions when searching for a new location. Sensitivity analysis to customer demands was made to show the robustness of the solutions. Maharjan and Hanaoka [19] also determined warehouse locations in a particular setting in Nepal. The authors used a modified version of the maximal covering location problem which concerned additional constraints reflecting the real situation in Nepal. They considered development, disaster safety, and transportation accessibility in Nepal in order to propose the number of locations of warehouses and their coverage. Natalia et al. [20] determined the optimal warehouse location by using the Center of Gravity method for a case study in Indonesia. The final location was selected among some specified cities in the country. Lestari et al. [21] examined a fast-food restaurant brand in Indonesia. There were three stages in their study: compiling data, cluster analysis, and network analysis. Cluster analysis was used to consider the location of the additional distribution center.

The current article is a variant version of Monthatipkul [2]. It applies the model proposed by Monthatipkul [2] to a real case study in Thailand. The model of Monthatipkul [2] concerns only a single type of product. This paper focuses on the multiple product scenario. In terms of a contribution in the methodology, a more realistic and accurate weight factor and model are developed. A suitable location of the new second warehouse was suggested based on the firm's policies and restrictions, and land prices.

3. Mathematical Model

The following notations are used to present the model. The objective function

Indexes:

i	retailer index ($i = 1, 2, 3, ..., I$)
j	distribution center index ($j = 1, ..., J$)
k	product index ($k = 1, 2, 3, ..., K$)

Given data:

A_i	x-coordinate (longitude) of retailer i
B_i	y-coordinate (latitude) of retailer i
$x_{j=1}$	x-coordinate (longitude) of distribution center 1 (current distribution center)
$y_{j=2}$	y-coordinate (latitude) of distribution center 1 (current distribution center)
DD_{ij}	displacement distance from distribution center j to retailer i (kilometer)
FCF_{ij}	fuel consumption factor from distribution center j to retailer i (baht / kilometer · ton)
FCB_{ij}	fuel consumption factor back from retailer i to distribution center j (baht / kilometer)
NT_{ij}	estimated number of trips from distribution center j to retailer i (trip / year)
FD_{ik}	forecasted demand of product k at retailer i (pieces / year)
V_k	Volume of product k (cubic meter)
TC_{ij}	transportation capacity from distribution center j to retailer i (cubic meter / trip)

W_k Weight of product k (kilogram)
WF_{ij} Weight factor associated with distribution center j and retailer i

Main decision variables:

se_{ij} a binary number, if distribution center j is selected for retailer i, otherwise $se_{ij} = 0$
$x_{j=2}$ x-coordinate (longitude) of the new distribution center
$y_{j=2}$ y-coordinate (latitude) of the distribution center

is expressed as follows:

$$\text{minimize } z = \sum_j \sum_i se_{ij}\{(DD_{ij}FCF_{ij}NT_{ij} WF_{ij}) + (DD_{ij}FCB_{ij}NT_{ij})\} \quad (3.1)$$

subject to

$$DD_{ij} = \{(x_j - A_i)^2 + (y_j - B_i)^2\}^{\frac{1}{2}} \quad (3.2)$$

$$NT_{ij} = \frac{\sum_k (FD_{ik}V_k)}{TCij}, \text{ for all } i, j, \quad (3.3)$$

$$WF_{ij} = \frac{\sum_k (FD_{ik}W_k)}{1000NT_{ij}}, \text{ for all } i, j, \quad (3.4)$$

$$\sum_j se_{ij} = 1 \quad \text{for all } i, \quad (3.5)$$

$$x_j = 2, \quad y_j = 2 \geq 0, \quad (3.6)$$

$$se_{ij} \text{ is binary} \quad \text{for all } i, j. \quad (3.7)$$

The model is for determining the location of the new warehouse ($x_{j=2}, y_{j=2}$) so as to minimize the sum of weighted displacement distances (DD_{ij}) from two distribution centers to all retailers restricted by the allocation policy. Eq. (3.1) represents the objective function. The displacement distance DD_{ij} is weighted by the terms $(FCF_{ij}\ NT_{ij}\ WF_{ij}) + (FCB_{ij}\ NT_{ij})$. The first term is the product of fuel consumption rate, estimated number of trips, and average weight per trip. The second term is the function of fuel consumption rate and estimated number of trips. The difference between these two terms is the unit of measure of FCF_{ij} and FCB_{ij}. The factor FCF_{ij} concern the weight of the products (kilograms) when transporting them, while the factor FCB_{ij} excludes the weight of products because it represents backhaul. The displacement distance DD_{ij} is calculated by Eq. (3.2). It is based on the Pythagorean theorem. This research uses the displacement distance (Euclidean distance) rather than the actual distance, because finding the actual distance from an unknown location of the new distribution center is too cumbersome. Eq. (3.3) shows that the factor NT_{ij} is obtained by the total volume of forecasted product demand divided by the transportation capacity per trip. It is a figure representing frequency of transport. The weight factor WF_{ij} can be determined by Eq. (3.4). It represents the average number of weights per trip. Eq. (3.5) enforces that each retailer must be assigned to only one distribution center. Finally, Eq. (3.6) and Eq. (3.7) are the non-negativity and the binary conditions, respectively.

4. Numerical Example

This section contains a numerical example to illustrate the application of the mathematical model and a solution approach. Suppose that an old distribution center supplying ten products to twenty retailers is located at the coordinate of (6, 10). Locations of all retailers are within the range 0-10 (see Fig. 1). Demand of each product is uniformly generated within the range of 10,000-50,000 pieces. Other necessary data are given in Tables 1-3. The model is solved by using the GRG option embedded in the Microsoft Excel Solver. The initial solutions are randomly assigned within the range 0-10 in order to determine different local optimal solutions. For each run, after a local optimal solution is found, the solver is repeatedly run until the result in no longer improved. The best optimal solution is then selected to be the final location of the new distribution center. Table

4 and Fig. 1 show the results. As shown

Table 1. Given data used in the numerical example.

i	A_i	B_i	k	V_k	W_k
1	4	2	1	0.06	0.4
2	10	5	2	0.04	0.8
3	1	5	3	0.06	0.6
4	6	9	4	0.03	0.8
5	5	7	5	0.01	0.4
6	9	4	6	0.02	1
7	2	1	7	0.1	1
8	7	10	8	0.08	0.8
9	4	4	9	0.09	0.8
10	3	9	10	0.1	0.3
11	10	5			
12	10	10			
13	2	6			
14	4	5			
15	9	2			
16	2	1			
17	4	6			
18	8	3			
19	10	6			
20	3	4			

in Table 4, the new distribution center is located at the coordinate of (4.28, 4.20). The objective function value is 358,172. All binary variables se_{ij} are shown on the right-hand side. It confirms that each retailer is assigned to only one distribution center depending on its related weighted displacement distance. Fig. 1 shows the graphical solution. It is noted that there are only four retailers supplied by the old distribution center. All of them are located in the upper part of the boundary. The remaining retailers at the lower part of the boundary are allocated to the new distribution center.

5. Application to the Case Study

5.1 Numerical experiments

The proposed mathematical model was applied to the garment case study. Numerical experiments, which were based on the actual data (with some modifications) of the case study, were conducted using the Premium Solver (www.solver.com). The company supplies 66 retailers located in Bangkok and perimeter. The current distribution center was at Kingkaew Road, Samut Prakan province. The case study utilized two types of trucks: four-wheel trucks and six-wheel trucks. Table 5 provided all important data of the case study. The experiments were collectively run for 10 years.

Table 2. (cont.) Given data used in the numerical example.

FCF_{ij}			FCB_{ij}		
i	$j=1$	$j=2$	i	$j=1$	$j=2$
1	0.8	0.7	1	1.3	1.1
2	0.4	0.5	2	1.3	1.2
3	0.3	0.9	3	1.1	1.3
4	0.3	0.3	4	1	1.3
5	1	0.3	5	1.5	1.5
6	0.9	0.1	6	1.4	1.5
7	0.8	0.3	7	1.5	1
8	0.1	0.3	8	1.1	1.3
9	1	0.6	9	1.1	1.1
10	0.2	0.2	10	1.2	1.3
11	0.2	0.7	11	1.5	1.3
12	0.4	0.1	12	1	1.2
13	0.8	0.2	13	1.3	1.4
14	0.6	0.9	14	1.1	1
15	0.1	0.3	15	1	1.3
16	0.6	0.5	16	1.2	1.4
17	0.9	0.8	17	1.4	1.2
18	0.2	0.2	18	1.5	1.5
19	0.8	0.5	19	1.1	1.2
20	0.9	0.2	20	1.4	1.2

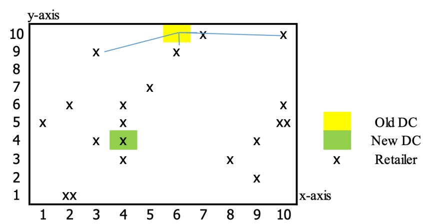

Fig. 1. Graphical solution of the example.

Table 3. (cont.) Given data used in the numerical example.

Retailer	TC_{ij}	
i	$j = 1$	$j = 2$
1	6	6
2	7	7
3	9	6
4	6	6
5	8	8
6	10	10
7	7	7
8	8	8
9	10	10
10	10	10
11	6	9
12	7	8
13	7	8
14	10	6
15	8	10
16	8	8
17	9	8
18	9	8
19	7	9
20	8	7

Table 6 concludes the results. The new distribution center was proposed to be located in the middle of Bangkok at Phayathai district (N13.750817, E100.531115). It was approximately 24 kilometers from the old distribution center, which was located near to the Suvarnabhumi International airport (see Fig. 2). From Table 6, there were two groups of retailers. Fifty-eight of them were assigned to the new distribution center, only eight retailers were assigned to the old distribution center. Fig. 3 illustrated allocation of retailers between the two distribution centers. It is noted that a majority of retailers, which were located on the west side, are served by the new distribution center. The old distribution center, which is located in the east side, serves only eight retailers.

Table 4. Solution of the numerical example.

Distribution Center (DC)		
	x_j	y_j
Old DC	6	10
New DC	4.28	4.2

Objective Function Value
358,172

Retailer	Location		se_{ij}	
i	A_i	B_i	$j = 1$	$j = 2$
1	4	2	0	1
2	10	5	0	1
3	1	5	0	1
4	6	9	1	0
5	5	7	0	1
6	9	4	0	1
7	2	1	0	1
8	7	10	1	0
9	4	4	0	1
10	3	9	1	0
11	10	5	0	1
12	10	10	1	0
13	2	6	0	1
14	4	5	0	1
15	9	2	0	1
16	2	1	0	1
17	4	6	0	1
18	8	3	0	1
19	10	6	0	1
20	3	4	0	1

Table 5. Given data of the case study used in the numerical experiments.

Data	Values
I	66
J	2
K	10,000
$x_{j=1}$	13.694803
$y_{j=2}$	100.724266
FD_{ik}	1,000 - 150,000
V_k	0.01 - 0.10
TC_{ij}	5 - 30
W_k	0.30 - 1.00
A_i	99.550000 - 101.050000
B_i	12.390000 - 16.850000
FCF_{ij}	Between 0.8 and 2.0
FCB_{ij}	Between 2.0 and 4.2

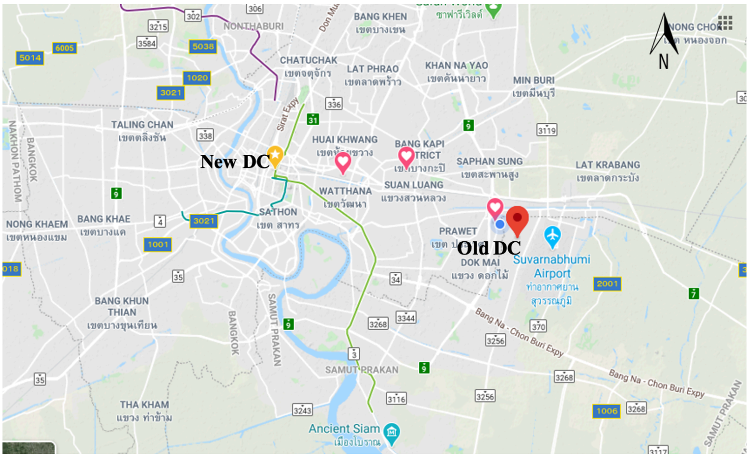

Fig. 2. Locations of the old and new distribution centers.

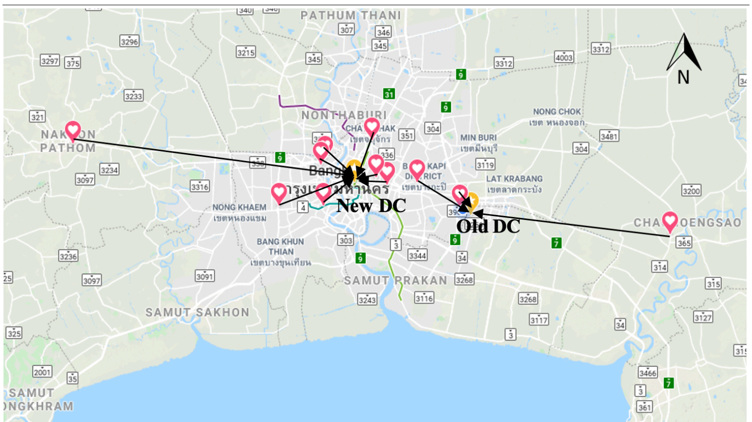

Fig. 3. Allocation outline of retailers between two distribution centers.

Table 6. Solutions for the case study from the 10-year experiments.

List	Values
Objective function value	37,690.76
Longitude of the new DC, x_2	N 13.750817
Latitude of the new DC, y_2	E100.531115
Number of retailers assigned to old DC	8
Number of retailers assigned to new DC	58

5.2 Sensitivity analysis of retailer demand

Since the amount of forecasted demand at each retailer affected the location of the new distribution center, sensitivity analysis of retailer demand was performed to study the robustness of the obtained solution. The case study divided the products into three main groups: Growth Product (GP), Stable Product (SP), and Declining Product (DP). This research focused on sensitivity analysis due to increasing the demand in the GP group. Supposing that demand of all products in the GP group was increased by 25%, 50%, 75%, and 100%, the proposed model was rerun to obtain the solutions. The experiments were repeated for 30 replications. Fig. 4 shows the results. The circle in Fig. 4 represents a boundary of the location, when demand of products was increased. Its radius was only 500 meters from the location of the new distribution center.

Fig. 4. Boundary of location movement under sensitivity analysis of retailer demand.

5.3 Location analysis due to specified boundaries

Since the proposed location of the new distribution center was in the middle of the city, the availability of land and prices must be the main concern. Due to these concerns, the top management had offered some areas, which could be the boundaries of the new search. Fig. 5 showed the boundaries of the new search. From Fig. 5, the new search must not be within the middle of the city represented by the square. The location of the new distribution center could be in the north, east, west, or south direction. Fig. 6 shows the result. The location of the new distribution center moved to Taling Chan district (N13.77703, E100.428585) on the west side of Bangkok.

To sum up, for the management team, we recommended a solution for this particular setting as follows. The location of the new distribution center without considering land prices and availability should be in Payathai district (N13.750817, E100.531115). The management team should explore the area to see if there is land available or not, and if the company could afford the land or not. If so, a more-in-depth feasibility study should be performed. Nevertheless, in the case of high prices or unavailability of land, the case study should consider a location in the Taling Chan district on the west side of Bangkok. This recommendation can be useful in the selection of the location of the new distribution center in the future.

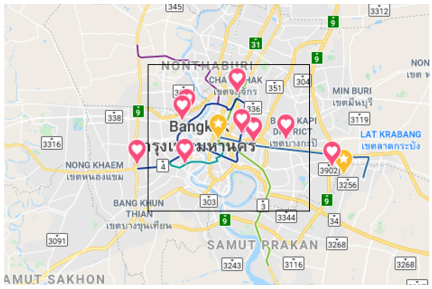

Fig. 5. Boundaries of the new search due to land prices and availabilities.

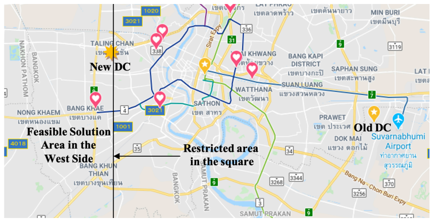

Fig. 6. Location of the new distribution center after considering the restricted area.

6. Conclusion

This article analyzed a specific problem of a garment distributor in Bangkok, Thailand. A variant version of the mathematical model developed by Monthatipkul [2] was formulated. The original version was concerned with only a single type of product, while this paper focused on the multiple product case, which could result in more complicated weight factors, when calculating a location of a new facility. The proposed model was then used to suggest a location of the new distribution center. From the numerical experiments based on actual data of the case study, it was found that the location of the new distribution center should be in Phayathai district (in the middle of Bangkok). It was also noted that if a new distribution center was set up in Phayathai district, it would supply a majority of retailers (fifty-eight retailers), while only a few retailers (eight retailers) would be served by the old distribution center, which is located on the east side of Bangkok. This result implied that the old distribution center is located at an unsuitable site. However, when land prices and availability in the middle of Bangkok were an obstacle, direction of the movement of the new location went to the west side (Taling Chan district).

In general, this article provides guidance for suggesting a location for a new facility in a multiple-product case. It provides a more accurate location since the more accurate weight factor is taken into account. It considers the combined effect among product demands, product weights, product volumes, fuel consumption rates and capacities of transportation mode. It can be noted that the proposed model contributes a more accurate loading factor for the Load Distance technique, which has been widely used in the field of continuous facility location problems. Moreover, the main research implication is an ability of the model to prove whether the current distribution center site is located properly or not (as shown in Fig.3). If the top management has decided to open one more new distribution center, the model can suggest a suitable location. The interesting parties can utilize the proposed model for this particular purpose for their own cases.

Despite some advantages, the study has some disadvantages or limitations: limitation of actual-distance determination, forecasted demand and customer sites from historical data only, opening of only one new distribution center other than multiple new distribution centers.

The work in the future of the case study should focus on a feasibility study of opening a new distribution center in the new place. A survey of the actual place should be conducted as well. In terms of further study in the methodology, a mathematical model for multiple new distribution centers should be developed. If multiple sites of distribution centers are allowed, the research question must extend to ”Should new distribution centers be opened?”, and the objective function must also include some other significant costs, for example, facility setting-up cost, warehousing costs, etc.

References

[1] Gergin RE, and Peker I. Literature review on success factors and methods used in warehouse location selection. Pamukkale Univ Muh Bilim Derg 2019;25(9):1062-70.

[2] Monthatipkul C. A non-linear program to find an approximate location of a second warehouse: a case study. Kasetsart J of Social Science 2016;37:190-201.

[3] Weber A. (1909). Uber den standort der industrien, tubingen, [The theory of the location of industries]. Chicago IL: Chicago University Press; 1909.

[4] Weiszfeld E. Sur le point pour lequel la somme des distances de n points donnes est minimum. Tohoku Mathematical Journal 1937;43:355-86.

[5] Kulin HW, Kuenne RE. An efficient algorithm for the numerical solution of the generalized Weber Problem in spatial economics. J Regional Science 1962;4:21-34.

[6] Tellier L. The Weber Problem: solution and interpretation. Geographical Analysis 1972;4(3):215-33.

[7] Kulin HW. A note on Fermat's problem. Mathematical Programming 1973;4:98-107.

[8] Rautenbach D, Struzyna M, Szegedy C, Vygen J. Weiszfeld's algorithm revisited once again (Report No. 04946-OR). Bonn: Germany; 2004.

[9] Tellier L. Economie spatiale: rationalite economique de l'espace habite [Spatial economy: economic rationality of inhabited space]. Montreal: Quebec, Canada: G. Morin Publisher; 1985.

[10] Chen P, Hansen P, Jaumard B, Tuy H. Weber's problem with attraction and repulsion. J of Regional Science 1992;32:467-86.

[11] Korte B, Vygen J. Combinatorial optimization: theory and algorithms. Berlin: Springer; 2000.

[12] Vardi Y, Zhang CH. A modified Weiszfeld algorithm for the Fermat-Weber Problem. Mathematical Programming 2001;90:559-66.

[13] Szegedy C. Some applications of the weighted combinatorial laplacian [Ph.D.thesis]. Germany: University of Bonn; 2005.

[14] Drezner Z, Klamroth K, Schobel A, Wesolowsky GO. The Weber Problem. In Drezner Z, Hamacher HW. (Eds.), Facility location: applications and theory (pp 1-36). New York: Springer-Verlag; 2002.

[15] Brimberg J, Drezner Z, Mladenovic N, Salhi S. A new local search for continuous location problems. European Journal of Operational Research 2014;232(2):256-65.

[16] Drezner Z, Brimberg J, Mladenovic N, Salhi S. New local searches for solving the multi-source Weber problem. Annals of Operations Research 2015;2:1-23.

[17] Dhanashekar M, Kumar VSS. Selection of optimal warehouse location, based on demand and the shortest distance method. Proceedings of International Conference on Application of Optimization Techniques in Engineering; 2012; Kodaikanal, India: Available from: https://www.researchgate .net

[18] Chau TDL, Buddhakulsomsiri J, Jeenanunta C, Dumronhsiri A. Determining an optimal warehouse location, capacity, and product allocation in a multi-product, multi-period, distribution network: a case study. Int J Logistics Systems and Management 2019;34(4):510-32.

[19] Maharjan R, Hanaoka S. Warehouse location determination for humanitarian relief distribution in Nepal. Transportation Research Procedia 2017;25:1151-63.

[20] Natalia C, Prasetya W, Melina. Optimum warehouse location determination in humanitarian supply chain: a case study of BNPB Indonesia. Int J Science and Research 2018;7:1140-43.

[21] Lestari D, Widaningrum, Andika A, Murphiyanto RJ. Cluster analysis for determining distribution center location. IOP Conference Series: Earth and Environmental Science (Volume 109), The International Conference on Eco Engineering Development; 2017 Yogyakarta, Indonesia.