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Determination of the optimal distribution centre location with gravity location model

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Abstract. Distribution cost for an animal feed company in Deli Serdang is relatively difficult to reduce because the location of the distribution centre is not strategic and far from several distribution locations. The purpose of this research is to determine the optimal distribution centre location to reduce distribution costs. In determining the proposed distribution centre location, Gravity Location Model is used. The research results are the new coordinates as the proposed distribution centre location, namely (98.888504; 3.419406) and the total distribution costs of initial distribution centre location are Rp 7.135.828, while the total distribution cost of proposed distribution centre location is Rp 6.965.143. The results obtained show that the total distribution costs can be reduced by 2.39% per day.

1. Introduction

The role of distribution network and transportation is very vital. Distribution networks and transportation allow product to move from manufacture location to the customer location that is often limited by long distances. The ability to deliver the product to the customer on time, in the right amount and in good condition will determine whether the product will ultimately be competitive in the market. Therefore, the ability to manage distribution networks today is a component of competitive advantage that is very important for many industries [1].

To distribute a product, Company certainly need to decide the fastest and the most inexpensive route [2]. In determining a distribution route, pickup vehicle capacity and labor cost must also be considered by the company. With the optimal distribution route, the company not only minimize distribution cost but also increase customer satisfaction with on-time delivery [3]. In addition to the distribution route, the location of a strategic distribution center must also be considered by the company about its proximity to distribution locations or market.

Generally, the problems of scheduling and determining delivering route can have several objectives to be achieved, such as the aim to minimize delivering costs, minimize delivering time or minimize distance. In mathematical programming, one of the objectives can be an objective function and the other becomes a constraint function. For example, the objective function is to minimize delivering costs, but there are time window constraints, the maximum distance for each vehicle, vehicle capacity or other constraints [1].

In delivering its product, an animal feed company in Deli Serdang has difficulty in determining the optimal distribution route that leads to high distribution cost. The optimal distribution route which minimizes the distribution cost in current distribution center still considered high by company, so that



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the distribution center is proposed to be relocated. with this relocation, the company is expected to be able to easily distribute its product and spend less on distribution costs.

In this study, gravity location model is used to determine the location of the proposed distribution center. For iterations on gravity location model, Lingo 18.0 is used. Gravity location model is a model which used to determine the location of a facility that minimizes distribution costs from the warehouse to market. This model uses several assumptions, like the cost of distribution is assumed to rise linearly in proportion to the volume of products delivered and the location of both the distribution center and the market can be determined in x and y coordinates on the map [1,4].

2. Method

This research is descriptive research, research that describes a problem then discusses it so that it can produce a conclusion about the problem. The purpose of this research is to determine the location of a strategic distribution center that has an optimal distribution route and minimum costs. The data used in this research is product demand data, distribution locations, and pick-up vehicle capacity data, which are obtained from the company, while the distance between distribution locations with the distribution center and distribution location coordinates are obtained through google maps application.

The methods used in this research are saving matrix method and VRP method. These methods are used to determine the route and distribution costs, while to determine the new location of the distribution center, gravity location model is used.

2.1. Saving matrix

The saving matrix method is a method used to minimize distance, time or cost. With saving matrix method, the saving value obtained by combining distribution locations in the same route. The obtained value will determine the optimal distribution route. The following are the steps for saving matrix method [1].

2.1.1. Distance matrix identification. Identification of the distance matrix is done by calculating the distance between the distribution center and distribution location where the product will be delivered and the distance between each distribution locations.

2.1.2. Saving matrix identification

$$S(x, y) = D(DC, x) + D(DC, y) - D(x, y) \quad (1)$$

Where:

S = Saving value

D = Distance between locations

The distance data from the first step is used in this step. Saving value is identified by using formula (1).

2.1.3. Distribution locations allocation to distribution routes. The distribution location where the product will be delivered is allocated to the route based on the order of the largest saving value.

2.1.4. Sort the distribution locations on the routes with the nearest neighbour principle. Distribution locations that have been allocated to the optimal route are sorted according to the nearest neighbor principle. The nearest neighbor principle is to always add the location closest to the last visited location.

2.2. Vehicle routing problem (VRP)

Vehicle routing problem is an optimization problem in determining distribution route with the constraint on vehicle capacity. the vehicle routing problem, demands from customers are supplied by one or several depots. The purpose of vehicle routing problem method is to find delivering route that meets the requirements or constraints and provides a minimum total distribution cost [5]. On the vehicle routing problem, the data needed are distance data between distribution locations, distance data between

distribution locations and depots and vehicle capacity data. For the formulation of vehicle routing problem is as follows [6,7]:

Minimize:

$$\sum_{i \neq j} d_{ij} x_{ij} \quad (2)$$

Subject to:

$$\sum_j x_{ij} = 1, \forall i, i \neq j \quad (3)$$

$$\sum_i x_{ij} = 1, \forall j, i \neq j \quad (4)$$

$$\sum_{i,j \in S} x_{ij} \leq |S| - 1 \quad (5)$$

$$\sum_{i,j \in T} x_{ij} \leq |T| - k \quad (6)$$

Where:

i, j = distribution location

d_{ij} = distance between location i and location j

k = minimum number of locations that must be dropped from T to reduce it to one load

$x_{ij} = 1$, if a route from location a to location b is formed

The objective is represented by (2), which is to minimize the total distance. Constraint (3) ensures each location j be visited once. Constraint (4) ensure each location i be exited once. Constraint (5) for no sub-tours and constraints (6) for no overloads.

2.3. Gravity location models

This model is used to determine the location of a facility as a connector between the distribution center or warehouse with market or customer with the aim of minimizing distribution costs. For the formulation of gravity location model is as follows [8-10]:

Minimize:

$$\sum_i C_i Q_i d_i \quad (7)$$

Subject to:

$$d_i = ((x_n - x_i)^2 + (y_n - y_i)^2)^{1/2} \quad (8)$$

$$x_n = \sum_i \frac{C_i Q_i x_i}{d_i} \left(\sum_i \frac{C_i Q_i}{d_i} \right)^{-1} \quad (9)$$

$$y_n = \sum_i \frac{C_i Q_i y_i}{d_i} \left(\sum_i \frac{C_i Q_i}{d_i} \right)^{-1} \quad (10)$$

Where:

i = Distribution location

x_n = Coordinate x new distribution centre iteration n

y_n = Coordinate y new distribution centre iteration n

x_i = Coordinate x distribution location i

y_i = Coordinate y distribution location j

- Q_i = Quantity of products delivered to distribution location i
 C_i = Cost for sending products to distribution location i

The objective of gravity location model is represented by (7). Equation (9) and (10) are used to determine the coordinate of iteration n and then the coordinates are substituted to equation (8) to yield new coordinates. The iteration will keep repeating until the same coordinates are obtained which will be the optimal facility coordinate.

3. Results

3.1. Calculation of initial distribution center distribution cost

The first stage in this research is to calculate the distribution cost of the initial distribution center. To calculate distribution cost, saving matrix method and vehicle routing problem method are used. The results of both methods can be seen in table 1.

Table 1. The initial distribution center distribution cost.

Method	Number of routes	Number of deliveries	Products delivered	Total distance (km)	Total cost
Saving matrix	31	2	3.989	1.304	Rp 7.159.371
VRP	31	2	3.989	1.272	Rp 7.135.828

From the result in table 1, can be seen that the vehicle routing problem method has a lower total cost compared to the saving matrix method. Thus, the minimum total cost at the initial distribution center is Rp 7.135.828.

3.2. Determining the location of the proposed distribution center

To determine the location of the proposed distribution center, gravity location model is used. The iteration of this model will be assisted by using Lingo 18.0 software. The result of the proposed distribution center location can be seen in table 2.

Table 2. Result of the proposed distribution center location with Lingo 18.0 software.

Variable	Value	Reduced Cost
Total Cost	922929.9	0
X_n	98.88504	0.8873030E-07
Y_n	3.419406	0

From the result in table 2, can be seen that the coordinate of the proposed distribution center is (98.88504;3.419406). The total cost in table 2 is the objective value of this model. The coordinate of proposed distribution center location is used to determine the new distance matrix.

3.3. Calculation of proposed distribution center distribution cost

Based on the new distance matrix data obtained through coordinate of the proposed distribution center, distribution cost of the proposed distribution center can be calculated. To calculate distribution cost, saving matrix method and vehicle routing problem method are used. The results of both methods can be seen in table 3.

Table 3. The proposed distribution center distribution cost.

Method	Number of routes	Number of deliveries	Products delivered	Total distance (km)	Total cost
Saving matrix	31	2	3.989	1.075	Rp 6.990.893
VRP	31	2	3.989	1.040	Rp 6.965.143

From the result in table 3, can be seen that the vehicle routing problem method has a lower total cost compared to the saving matrix method. Thus, the minimum total cost at the proposed distribution center is Rp 6.965.143.

4. Discussion

In the calculation of distribution cost for initial distribution center location obtained a result of Rp 7.135.828. This result is the optimal result that can be applied to the initial distribution center. Then, in the calculation of distribution cost for the proposed distribution center location obtained Rp 6.965.143 as the optimal result. This cost is smaller than the previous cost. If calculated, the proposed distribution center will reduce cost by 2,39% per day. Beside cost aspect, the total distance that must be taken by pickup vehicle at the proposed location is also shorter than the initial location. The difference in the distribution route between the initial distribution center and proposed distribution center on the map can be seen in figure 1 and figure 2.



Figure 1. Distribution route map of initial distribution center.



Figure 2. Distribution route map of proposed distribution center.

From figure 1 and figure 2 can be seen that the location of the proposed distribution center is more centralized than an initial distribution center. Based on distribution routes in figure 1 and figure 2, the total distance, number of routes and distribution cost for each distribution center can be seen in table 4.

Table 4. Comparison between initial DC and proposed DC.

	Initial DC	Proposed DC
Total distance	1.272	1.040
Number of routes	31	31
Cost	Rp 7.135.828	Rp 6.965.143

5. Conclusion

Based on the analysis using saving matrix method and vehicle routing problem method, the optimal cost for initial distribution center is Rp 7.135.828 with a total distance of 1.272 km. Then, for analysis with the same method at the proposed distribution center, the optimal cost is Rp 6.965.143 with a total distance of 1.040 km.

From the results above, can be concluded that the relocation of the distribution center will have a positive impact on the company. With the existence of the proposed distribution center, distribution cost per day can be reduced by Rp 170.685 or 2,39% from initial distribution cost.

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