Application of Geographic Information Systems for Locating Distribution Center of Latex Pillow Product

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Abstract. Nowadays, most of latex pillow products in case study are produced and stored all in 5 warehouses located in southern region of Thailand which causes inconvenience to satisfy the customers’ orders from other regions that is far away from current sites. Therefore, the main purpose of this study is to determine the optimal locations and number of distribution centers (DCs) that is one of the important ways to increase the potential to response to the customers’ needs. By applying the geographic information system (GIS) with maximize coverage model in location-allocation problems, the solution was covering as many customers as possible within the services distance of distribution centers, including establishing cost of the distribution centers. The finding of this study found that two optimal distribution centers, Dong Khoi in Phetchabun Province and Nong Sai in Suratthani Province, where cover as 99.99% of demands within the service distance 500 kilometers and there were establishing cost of both is 2.55 million Baht.

1. INTRODUCTION
In south of Thailand, rubber farmers are facing the problem of income decline because of the price reduction of rubber latex. So, they have tried to develop more value products instead of primary products such concentrated latex, smoked sheet rubber, or block rubber. Thus, they have united into organization, so called cooperative, to produce the latex pillow in order to heighten the value of concentrated latex for domestic market of Thailand. However, most of rubber pillows are currently produced and stored all in five production sites where located in southern region of Thailand which take quite a long time to respond the customers’ orders from other regions that are far away from current sites. This is major factor that is affecting the competitiveness of rubber farmers’ cooperatives inferior to private sector. Thus, the motivation of this research endeavored to increase competitiveness for them.

One of the key strategic competitiveness from logistics management perspective is location decision. In designing the location of distribution center is one of important concern to reduce response time to
customers’ needs and it is the big advantages of having all products from many plants coming to optimal location. There are many research studies related to distribution center location finding. Ronald A. Halim et al. [1] combined of a multi-objective optimization model to estimate locations and networks of distribution centers for port-hinterland freight distribution networks and they also measured port-hinterland transport cost, port-hinterland transport time, and distribution center-hinterland transport time for this study. Kudda Kitsawat [2] studied of warehouse leasing in the provinces in order to reduce transportation costs and reduce time to ship their products. Linear programming was used to analyze the right warehouse location and low cost. Rantala [3] combined center of gravity method and analytic hierarchy process (AHP) method in location decision to find optimal location for Kalmar’s European distribution center.

In addition, geographic information system (GIS) is applied to solve many problems for finding and selecting the optimal location within different situations and conditions. Eddie W. LL Cheng et al. [4] applied GIS to select optimal shopping mall location where can cover maximum customers and minimum distance. Wei Gu et al. [5] designed a hybrid heuristic algorithm for GIS data by genetic algorithm and simulated annealing techniques to develop service information system and the goals included reducing the distribution cost, increasing the efficiency, satisfying customer demands, and improving service quality. Nutt Tongkum et al. [6] used GIS to analyze the potential of new mail center in the upper north region where can serve the entire study areas which are the shortest distance and meet the conditions of the agency. Therefore, the main purpose of this study is to determine the distribution center location (see figure 1) and there are two questions to answer “Where should they be located?” and “How many DCs should there be?” for locating the optimal DCs. [7]

![Figure 1](image.png)

**Figure 1.** Designed location-allocation system of distribution center for latex pillow product.

The first question “Where should they be located?” was answered by applying the geographic information system and used maximize coverage model in location-allocation problem. Maximize coverage chooses DCs from candidate sites such that as much demand as possible is covered by the impedance cutoff of DCs (see figure 2) [8]. And the second question “How many DCs should there be?” was fulfilled by the minimum establishing cost of DCs.
2. METHODS

There are four steps for this study (see figure 3) as follows:

![Flow chart of the methodology](image)

**Figure 2.** Graphic of maximize coverage model

**Figure 3.** Flow chart of the methodology

### Step 1: Data Collection
In this study, there are 5 rubber farmer cooperatives (5 plants). We collected their general data such as transportation costs, plant’s capacity, locations, etc. (see table 1.) And there are 3 customer groups to study [9] as show in table 2.

| Farmer Cooperative (Producer) | Capacity (pieces/month) |
|-------------------------------|-------------------------|
| 1 M1                          | 1,680                   |
| 2 M2                          | 12,000                  |
| 3 M3                          | 3,360                   |
| 4 M4                          | 16,800                  |
| 5 M5                          | 1,800                   |
| Total                         | 35,640                  |

| Customers          | Demands (pieces/year) |
|--------------------|-----------------------|
| 1 End users        | 43,229                |
| 2 Modern Trade     | 159,584               |
| 3 Retailers        | 225,075               |
| Total              | 427,680               |

### Step 2: Running ArcGIS program
For this step, there are 3 important data that is locations (latitude- longitude) and demands of each customer, location (latitude- longitude) of candidate sites, road network (see figure 4, 5, 6 and table 3.) After we obtained all data, we determined DCs location by ArcGIS 10.2 program by applying maximize...
coverage model to select the optimal locations for DC from candidate sites. We operated ArcGIS program within different number of DCs, i.e. 2, 3, 4, 5, 6, 7 and different covering distances, i.e. 300, 400, 500, 600 and 700 kilometers (see table 4.)

### Table 3. Data descriptions for using in ArcGIS program

| Data                      | Data type | Data Description                                      |
|---------------------------|-----------|-------------------------------------------------------|
| Customers                 | point     | Location and their demands                            |
| Candidate site            | point     | Location of nationwide sub district (7,349 points).    |
| Road Network              | Line      | Nationwide roads in Thailand                           |

![Figure 4. Location of candidate sites](image)

![Figure 5. Road network in Thailand](image)

![Figure 6. Location of all customers](image)

### Table 4. Parameters setting for running GIS program

| Setting          | Description                                      |
|------------------|--------------------------------------------------|
| Impedance Length | Limited by road network.                         |
| Travel From Facility to Demand | -                  |
| U-Turn at Junction | Allowed                   |
| Problem Type     | Maximize Coverage    | Math model is used.                                    |
| Facilities to Choose | 2-7              | The number of DC                                      |
| Impedance Cutoff | 300-700 km. | Services distance for coverage                      |

The maximize coverage model [10] can be formulated as follows:

**Objective function**

\[
\text{Maximize } \left\{ Z = \sum_{i=1}^{68} u_i y_i \right\} \tag{1}
\]

**Subject to:**

\[
y_i \leq \sum_{j \in N_i} x_j \quad i = 1, 2, \ldots, 68 \tag{2}
\]

\[
\sum_{j=1}^{7349} x_j = p \quad j = 1, 2, \ldots, 7349 \tag{3}
\]

\[
x_j, y_i \in \{0, 1\} \quad i = 1, \ldots, 68 \quad j = 1, \ldots, 7349
\]
Notations are defined as follows:

\[ x_j = \begin{cases} 1 & \text{if DC located at } j \\ 0 & \text{otherwise} \end{cases} \]

\[ y_i = \begin{cases} 1 & \text{if demand node } i \text{ is covered} \\ 0 & \text{otherwise} \end{cases} \]

\[ a_i \] = The number of demand at node \( i \)

\[ N_i \] = The set of all candidate sites which can cover demand nodes \( i \); \( N_i = \{j | d_{ij} \leq s\} \)

\[ m \] = The number of demand locations (\( m = 68 \))

\[ n \] = The number of candidate DCs (\( n = 7,349 \))

\[ s \] = Services distance for coverage (Impedance cutoff)

\[ p \] = The number of DC to be located

Equation (1) maximizes the number of covered demands. Equation (2) states that the demand at node \( i \) is covered whenever at least one DC is located within the impedance cutoff of DC. Equation (3) gives the total number of DC that can be located.

**Step 3: Determining the number of DCs**

We acquired number of demand nodes were covered by optimal DCs of each condition by running ArcGIS program from step 2. After that, the selected DCs within condition which covered 99.99-100% of demands were determined the number of DCs under the minimum establishing cost, including transportation cost, building cost and land cost.

3. **RESULT AND DISCUSSION**

The finding of ArcGIS program found that almost optimal DCs cover 99.99% and 100% of customers. Except, two DCs within services distance 300 kilometers and 400 kilometers cover 95.10% and 99.10% of customer demands, respectively. And three DCs within services distance 300 kilometers can cover 99.95% of customers (see table 5).

| No. of DC | Customers are covered (%) |
|----------|--------------------------|
|          | 300 km. | 400 km. | 500 km. | 600 km. | 700 km. |
| 2        | 95.10   | 99.10   | 99.99   | 100.00  | 100.00  |
| 3        | 99.95   | 100.00  | 100.00  | 100.00  | 100.00  |
| 4        | 100.00  | 100.00  | 100.00  | 100.00  | 100.00  |
| 5        | 100.00  | 100.00  | 100.00  | 100.00  | 100.00  |
| 6        | 100.00  | 100.00  | 100.00  | 100.00  | 100.00  |
| 7        | 100.00  | 100.00  | 100.00  | 100.00  | 100.00  |

Then, selecting DCs within condition which covered 99.99-100% of customers were additionally analyzed the number of DCs with the minimum establishing cost, including transportation cost, building cost and land cost (see table 6).
Table 6. Establishing cost of DCs within different services distance.

| No. of DC | Establishing cost (million Baht) |
|-----------|----------------------------------|
|           | 300 km.  | 400 km.  | 500 km.  | 600 km.  | 700 km.  |
| 2         | 2.49     | 2.52     | 2.55     | 2.59     | 2.61     |
| 3         | 2.61     | 2.58     | 2.68     | 2.59     | 2.61     |
| 4         | 22.74    | 2.58     | 2.68     | 38.29    | 20.82    |
| 5         | 22.74    | 38.27    | 22.77    | 22.81    | 22.81    |
| 6         | 15.70    | 22.79    | 22.80    | 22.80    | 22.80    |
| 7         | 22.69    | 18.24    | 18.25    | 18.25    | 18.25    |

From table 6 found that two DCs within service distance 500 kilometers cover 99.99% of demand, there are the minimum of establishing cost that is 2.55 million Baht. Two DCs is In Dong Khoi, Chon Daen District, Phetchabun and Nong Sai district, Phunphin district, Surat Thani (see figure 7)

4. CONCLUSION

Applying the geographic information system (GIS) with maximize coverage model in location-allocation problem to find location and number of distribution centers under the minimum establishing cost, it found that two optimal distribution centers, Dong Khoi in Phetchabun Province and Nong Sai in Suratthani Province where cover 99.99% of demands within the services distance 500 kilometers with establishing cost of both is 2.55 million Baht. Establishing and locating DCs of cooperatives is one of the strategic competitiveness to increase the ability to respond to the customers’ needs. Ultimately, they can compete with other private manufacturers in the domestic market.

5. REFERENCES

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