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Research Article

Solving the Location Routing Problem of the Central Rubber Market by Tabu Search

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Abstract

The central rubber market of Songkhla province is the center of the collection and distribution of rubber production from sellers to purchasers. It is considered ineffective because sellers need to deliver whole raw rubber to the market, resulting in high transport costs, especially for those who came a great distance and had little quantity. This research applied the tabu search method to solve the location selection problem of the rubber purchasing depot and manage transport routes to the market. Results found that there were 16 purchasing depots. The central rubber market had unlimited purchasing capacity while the other purchasing depots limited the quantity of rubber to 10 tons. There were five transport routes and five trucks (four ten-wheeled trucks and one ten-wheeled truck with a trailer). The total delivery costs were 53,313.89 baht per day. The answers about efficiency from the Lingo 13 program with small, medium, and large problems and real problems were not significantly statistically different at a significance level of 0.05.

Keywords: Location routing problem, Central rubber market, Tabu search

1 Introduction

Natural rubber is an essential economic plant of the southern Thai region which has a plantation area of 9.90 million rais, accounting for 71.7 percent of the country. Most plantations are in Surat Thani province (1.73 million rais), Songkhla (1.27 million rais), Nakon Si Thammarat (1.20 million rais) and Trang (1.18 million rais). 87.5 percent of the rubber is exported and the remaining 12.5 percent is used domestically. Most exported rubbers are in the form of block rubber, Ribbed Smoked Sheets (RSS), concentrated latex and rubber gloves. In addition, the rubber trees are also processed into timbles and particle boards to manufacture furniture components. The main export rubber market of Thailand includes China, Malaysia, Japan and the United States [1].

The Ministry of Agriculture and Cooperatives has recognized the importance of the development of the rubber market system of the country which is the basic of the development of the related rubber industries and is to create career security for rubber plantation. Therefore, the first central rubber market of Thailand was established at Amphur Hatyai, Songkhla on August 1, 1991 under the operation of the Rubber Research Institute, Department of Agriculture and was approved by Cabinet on December 17, 1991. The concept of the Central Rubber Market is that it be a fair and efficient distribution and collection center of rubber products between the sellers and the buyers and to be the place (location) for announcing the country's rubber auction prices [2].

The country's rubber market is considered to be inefficient with no system, and it has not been accepted by any organization due to the characteristics of the market as buyer owner, causing the farmers, the

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main producers of the country, to be in trouble about the unfair rubber prices, low standard rubber quality and the rubber weight not being the actual weight. These things affect the profession and income of rubber farmers directly. In the first operation period of the central rubber market, the sellers did not need to deliver all the rubber to the central market but just sent some samples to the market so that buyers could offer the auction price according to the quality of the sample rubber. The central market is a rubber collection source with different qualities or grades of rubber sent from the sellers and are a bargaining point. After that, each vendor will deliver the rubber to the winning bidder. Such an approach is not successful and does not benefit either buyers or sellers because when the seller has delivered the rubber to the buyer, there are often conflicting problems about rubber weight and quality. To solve these problems, the sellers must transport all the rubber to the central market and the rubber should be bought through the auction from buyers, but this method also has a problem due to different rubber prices; even though, in fact, whole rubber is of the same quality [3].

Facing these problems, the market service system has been improved and it is found that for a good central market system, the seller must deliver all rubber to the central market which will carry out services for all rubber procedures starting from grading, weighing, auctioning and payment, and including delivering the rubber to the buyer [3]. Another problem is that each vendor needs to deliver the whole amount of raw rubber to the central rubber market by himself. The locations of certain vendors are far from the central market and some vendors sometimes need to have a lot of rubber transported to the market, such as more than one truck load per day. These problems make transportation costs increase. Therefore, to have good management, purchasing depots are built to make the transportation distance shorter than distances from farmers' locations to the rubber market. This helps the rubber farmers or agriculturalists to have an opportunity to sell their products at good prices and also make the delivery costs decrease [4]–[6]. These are other ways to help the farmers according to policies of the central markets and the government as well [2].

With the importance of the problems mentioned above, this research focuses on solving the location selection problem efficiently and the solving of vehicle routing problems between the purchasing depot and the central rubber market [7]–[10] under the regulations and various constraints by good planning to reduce the sophisticated routes. Besides, it can also be applied to solve other forms of vehicle routing problems. Previously, this problem was very interesting because there were not many studies on it. Therefore, this research studies the central rubber market system by designing an algorithm for solving the problem of location selection of rubber purchasing depots and of managing vehicle routes from the purchasing depot to the central rubber market in order to make minimum economic (appropriate) total cost according to various windows.

2 Application of Tabu Search

Tabu Search [11]–[13] is a technique to find solutions and which has been developed from Local Search and been accepted to provide a final solution, avoiding Local Optimum. It enables one to search continuously until encountering a feasible solution close to Global Optimum. The search for a solution is allowed to cycle back to the forbidden area (Tabu list) defined by Aspiration Criteria and the diversity of search (Diversification) can be applied in order to cross-over Local Optimum.

Tabu Search is applied to solve the facility location problem along with vehicle routing problems of the central rubber market. It starts from building a set of purchasing depots and then assesses the optimizations from the objective function that enables one to investigate a violation of various constraints. After the locations of the depots are given, they are brought into the Tabu search process to determine their optimizations. Mobility means the partial change of the situation inside purchasing points in order to get to the new depot. The recent history of the changed situation is then stored in Tabu lists for one period. After that, the received purchasing depot will assess the optimization, as to whether or not it is the best solution. If it is the optimal solution, the operation will terminate. If it is not, the process continues further by partial adjustment of the situation inside the solution until achieving the optimal solution or until according to the constraints of stopping. On the part of the transportation route management (vehicle routing) it implements a similar characteristic of the location selection of the purchasing depot; however, it is operated after having already received the optimal purchasing depot.

3 Methodology

For the location selection problem of purchasing depots together with vehicle routing problems of the central rubber market, a total of 249 rubber sellers are involved, consisting of 1) 66 members of the Rubber Plantation Fund Cooperative (ORRAF), 2) 97 rubber collectors, and 3) 86 farmers. The owners of the open purchasing depots (Candidates) must only be sellers who are members of the ORRAF consisting of 66 persons.

3.1 *Data collection*

The researcher defines the position of the geographic coordinates of the rubber sellers' locations by using the Garmin eTrex 20 model GPS receiver, and the weight of rubber delivered to Songkhla central rubber market in 2555 B.E., which are shown in Table 1.

Table 1: Location coordinates and amount of individual seller's rubber

Order	Sellers	Volume (kg/year)
1	ORRAF of Kong Ra, Songkhla	100,404
2	Farmer Group, Phatthalung	7,658
3	ORRAF of Thungmaipak	144,096
.	.	.
.	.	.
248	T. Leamsom, A. Palian ,Trang	171,646
249	T. Udicharoen, Satun	2,278

The distance of each seller's location is measured by applying Google Maps and is then recorded in the form of a matrix table in Microsoft Excel. The accuracy of information is investigated by random measuring of the actual distances of 10 seller locations by using the automotive indicator. It is found that the actual distance is nearly equivalent to the GPS distance, with a difference of error of not more than 10%. The sample of distance matrix of rubber seller locations is shown in Table 2.

Table 2: Transportation distance of rubber seller location

Coordinate	0	1	2	…	248	249
0	0	13.4	69.7	…	172.0	103.0
1	13.4	0	69.3	...	172.0	98.9
2	69.7	69.3	0	…	108.0	103.0
.	.	.	.	…	.	.
.	.	.	.	…	.	.
248	172.0	172.0	108.0	…	0	66.1
249	103.0	98.9	103.0	…	66.1	0

3.2 *Mathematical model*

3.2.1 Index

i, j is the index of node for rubber depot; i and j are in the set $N = \{1, 2, \ldots, n\}$ and 1 is central rubber market

k is the index of vehicle used for rubber transport; k is in the set $K = \{1, 2, \ldots n\}$

l is the index of node for depot and rubber seller; l is in the set $M = \{1, 2, \ldots n\}$ and $N \subset M$

3.2.2 Parameters

C is the cost of transportation per unit of distance from depot i to central rubber market (baht/km)

E is the cost of transportation per unit of distance from rubber seller i to depot j (baht/km)

F_C is the depreciation of the central market (baht/depot/day)

F_S is the depreciation of depots (baht/depot/day)

H_k is the depreciation of vehicle transportation k (baht/car/day)

T_C is the maximum capacity of the central market (kg/day)

T_S is the maximum capacity of rubber depots (kg/day)

V_k is the maximum rubber loading of vehicle k (kg)

q_l is the volume of rubber sold by seller l (kg/day)

d_{ij} is the distance from i to j (km)

w_{ik} is the volume of rubber vehicle k transports to rubber depot i (kg)

3.2.3 Support decision variable

P is the number of rubber depots

u_{ik} is the support variable for sub tour

$$s_{ik} = \begin{cases} 1 & \text{vehicle k at rubber depot i} \\ 0 & \text{otherwise} \end{cases}$$

3.2.4 Decision variable

$$X_{ijk} = \begin{cases} 1 & \text{if going from node i to node j by vehicle k} \\ 0 & \text{otherwise} \end{cases}$$

$$y_i = \begin{cases} 1 & \text{if rubber depot is open at node i} \\ 0 & \text{otherwise} \end{cases}$$

$$z_{li} = \begin{cases} 1 & \text{the seller l sells rubber to depot i} \\ 0 & \text{otherwise} \end{cases}$$

$$v_k = \begin{cases} 1 & \text{if vehicle k is used} \\ 0 & \text{otherwise} \end{cases}$$

3.2.5 Objective function

The minimum sum of costs consists of the transportation cost from the seller to the depot, the transportation cost from the depot to the central market, the depreciation of the central market, depots and vehicles.

$$\begin{aligned} \text{Min } Z = {} & E\left(\sum_{i\in N}\sum_{l\in M} z_{li}(d_{il}+d_{li})\right)+ \\ & C\left(\sum_{i\in N}\sum_{j\in N}\sum_{k\in K} x_{ijk}d_{ij}\right)+ \qquad (1) \\ & F_S\sum_{i\in N, i\neq 1} y_i + \sum_{k\in K} v_k H_k \end{aligned}$$

3.2.6 Constraints

$$p = \left[\frac{\sum_{j=1}^{M} q_j}{T_c}\right] \qquad (2)$$

$$\sum_{i\in N} y_i = P \qquad (3)$$

$$\sum_{i\in N} z_{li} = 1, \quad \forall l \in M \qquad (4)$$

$$\sum_{l\in M} z_{li} q_l \le y_i T_S, \quad \forall i \in N,\ i \notin 1 \qquad (5)$$

$$\sum_{k\in K} w_{ik} = \sum_{l\in M} z_{li} q_l, \quad \forall i \in N,\ i \notin 1 \qquad (6)$$

$$\sum_{i\in N} w_{ik} s_{ik} \le v_k V_k, \quad \forall k \in K \qquad (7a)$$

$$w_{ik} = 0, \quad \forall k \in K \qquad (7b)$$

$$\sum_{j\in N} x_{ijk} = s_{ik}, \quad \forall i \in N,\ \forall k \in K \qquad (8)$$

$$\sum_{j\in N} x_{ijk} - \sum_{j\in N} x_{jik} = 0, \quad \forall i \in N,\ \forall k \in K \qquad (9)$$

$$u_{ik} - u_{jk} + Px_{ijk} \le P-1, \quad \forall i, j \in N,\ \forall k \in K \qquad (10)$$

$$s_{ik} \le y_i, \quad \forall i \in N,\ \forall k \in K \qquad (11a)$$

$$s_{ik} \le v_k, \quad \forall i \in N,\ \forall k \in K \qquad (11b)$$

$$s_{ik} \le w_{ik}, \quad \forall i \in N,\ \forall k \in K \qquad (11c)$$

$$s_{ik} \in \{0, 1\}, \quad \forall i \in N,\ \forall k \in K \qquad (12a)$$

$$v_k \in \{0, 1\}, \quad \forall k \in K \qquad (12b)$$

$$x_{ijk} \in \{0, 1\}, \quad \forall i, j \in N,\ \forall k \in K \qquad (12c)$$

$$z_{li} \in \{0, 1\}, \quad \forall i \in N,\ \forall l \in M \qquad (12d)$$

$$y_i \in \{0, 1\}, \quad \forall i \in N \qquad (12e)$$

Eq. (1) is the objective function aiming to determine the minimum sum of costs consisting of the transportation cost from the seller to the depot, the transportation cost from the depot to the central market, the depreciation of the central market, depots and vehicles. Eq. (2) stands for the number of open depots. Eq. (3) describes the number of open depot as P. Eq. (4) means each seller can send rubber to only one depot. Eq. (5) specifies the volume of rubber at depot i to be no more than the maximum capacity at rubber depot i. Eq. (6) shows that the volume of rubber transported to each depot is equal to the cumulative volume of rubber at the depot. Eq. (7a) means the volume of rubber delivered by vehicle k from the seller will not be more than capacity (V_k). Eq. (7b) specifies that the central rubber market does not have transportation. Eq. (8) shows that if sik equals 0, it means that vehicle k does not make a rubber delivery from seller i, or from node i to node j. In contrast, if s_{ik} is equal 1 it means the vehicle must transport rubber along one route. Eq. (9) specifies that vehicle k travelling to any node cannot remain at the node. Eq. (10) contains the prevention of a sub tour. Eq. (11a) means that there is no selection of vehicle k if the depot is not open. Eq. (11b) means that if there is no rubber delivery, then vehicle k is not selected. Eq. (11c) specifies that if there is no volume of rubber at depot i, vehicle k will not include that depot in the route. Eq. (12a)–(12e) are binary equations.

3.3 *The solution approach*

The development of the approach for solving the location selection problem with vehicle routing problem of central rubber market. The researcher presents tabu search [13], [14], which is divided into two parts: the first part is the establishment of initial solutions by applying randomization, and the second part is the improvement of initial solutions using neighborhood search, moving rubber selling points to find the best solution, consisting of five methods: 1) Exchange depot inside group 2) Swap move customer 1:1 3) Moving customers among the purchasing depots of one customer (Insert One-Move) 4) Exchanging customers among the purchasing depots of multiple customers (Swap Move Customer Many to Many), and 5) Moving customers within the purchasing depots of chain (Chain Insert One-Move). These assist to attain the optimal solution by finding in wider area. The researcher defines the solution parameters in Tabu search as shown in Table 3 and writes C# computerized language to find feasible solutions. The computer is processed according to the depot capacity and the truck capacity in six entire cases. Minimum cost is selected to be the optimal solution of the problem.

Table 3: The designation of related parameters for tabu search

Order	Parameter	Value
1	Tabu Size	100
2	Candidate List Size	2,000
3	Max Repeat Best	1,000
4	Max Iteration	10,000
5	Time Computation Seconds	30,000
6	Seller Assignment Method	Nearest
7	Depot Select Method	Random
8	Tabu List Improvement	Random

4 Results

The application for tabu search has tried to solve the location routing problem of the central rubber market. It consists of 6 cases; 1) depot capacity of 10 tons, (central market does not open depot), 2) depot capacity of 25 tons (central market does not open depot), 3) depot capacity of 50 tons (central market does not open depot), 4) depot capacity of 10 tons (central market opens depot), 5) depot capacity of 25 tons (central market opens depot), and 6) depot capacity of 50 tons (central market opens depot). The number of testing cycles in each case is given at 50 times to determine the minimum sum of costs. The best solution of each case is shown in table 4.

Table 4: Costs of location depots and transportation routing (baht/day)

Case	Sellers Assignment	Routing Vehicle	Depreciation of Depot	Depreciation of Vehicle	Total Costs
1	51,898.4	5,358.4	548.00	4,200.88	62,005.68
2	67,516.0	3,256.8	479.43	4,155.23	75,407.46
3	83,211.2	3,115.2	547.96	4,155.23	91,029.59
4	44,843.2	4,897.6	787.72	2,785.37	53,313.89
5	68,846.4	3,130.4	684.91	2,945.19	75,606.90
6	82,902.4	2,850.0	684.94	2,785.37	89,222.71

Table 5: The vehicle routing of central rubber market

Order	Routing	Volume of Rubber (kg)					Loading (kg)	Vehicle Size (kg)	Cost of Routing (baht/day)
		point 1	point 2	point 3	point 4	point 5			
1	0-5-37-59-0	927	9,300	9,452	-	-	19,679	20,000	1,487.2
2	0-28-17-46-14-6-0	8,009	6,818	4,464	1,923	3,591	24,805	25,000	1,570.4
3	0-57-45-54-0	9,428	4,218	2,952	-	-	16,598	20,000	935.6
4	0-50-60-0	9,843	9,975	-	-	-	19,818	20,000	346.0
5	0-2-66-0	9,994	9,780	-	-	-	19,774	20,000	558.4
Total		38,201	40,091	16,868	1,923	3,591	100,674	-	4,897.6

From the data in table 4, it was found that case 4 shows the minimum cost and it costs 53,313.89 baht/day in total. The central rubber market and office of Rubber Replanting Aid Fund (ORRAF) are totally opened for 16 depots. And table 5 shows 5 routes that used 4 vehicles with the capacity less than 20 tons and vehicles with the capacity less than 25 tons. The total cost of transportation is 4,897.6 baht/day.

5 Conclusions

The approach for solving the location routing problem of the central rubber market is case 4 which the capacity of purchasing is less than 10 tons (central rubber market opens depot) and the minimum cost is 53,313.89 baht/day. For this case, the transportation cost from the sellers to the depot is 44,843.2 baht/day. The transportation cost from rubber depot to central market is 4,897.6 baht/day. The depreciation of rubber depot is 787.72 baht/day and the depreciation of the vehicle is 2,785.37 baht/day. The total number of the rubber depot is 16 depots and the numbers of the vehicles for 5 routes are 5 vehicles. Compared to the former method which was direct shipping from the sellers to the central rubber market, the cost reduction is 115,113.11 baht/day or 68 percent. Furthermore, the measurement of the effective response with Lingo 13 indicates that there is no significantly statistical difference at significant level of 0.05.

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References

[1] Burean of Logistics Department of Primary Industries and Mines, *Optimizing the Logistics Industry in the South*, Bangkok: YC Media, 2014.

[2] Rubber Authority of Thailand, *Rubber Data*, Bangkok: Department of Agriculture Ministry of Agriculture and Cooperatives, 2013.

[3] S. Sikharinmat, S. Tongnuaka, R. Daoduang, and S. Karnjanapakorn, *Central Rubber Market Development Network*, Bangkok: Rubber Research Institute of Thailand, 2009.

[4] J. W. Escobar, R. Linfati, and P. Toth, "A two-Phase hybrid heuristic algorithm for the capacitated location-routing problem," *Computer and Operation Research*, vol. 40, pp. 70–90, 2013.

[5] V. F. Yu and S. Y. Lin, "A simulated annealing heuristic for the open location-routing problem," *Computer and Operation Research*, vol. 62, pp. 184–196, 2015.

[6] S. H. Huang, "Solving the multi-compartment capacitated facility location problem with pickup-delivery routes and stochastic demands," *Computer and Industrial Engineering*, vol. 87, pp. 104–113, 2015.

[7] M. Yaghini, M. Karimi, and M. Rahbar, "A hybrid metaheuristic approach for the capacitated p-median problem," *European Journal of Operational Research*, vol. 13, pp. 3922–3930.

[8] S. Dantrakul, C. Likasiri, and R. Pongvuthithum,

"Applied p-median and p-center algorithms for facility location problems," *Expert Sysem with Applications*, vol. 41, no. 8, pp. 3596–3604, 2014.

[9] J. Brimberg and Z. Drezner, "A new heuristic for solving the p-median problem in the plane," *Computer and Operation Research*, vol. 40, no. 1, pp. 427–437, 2013.

[10] R. Macedo, C. Alves, S. Hanafi, B, Jarboui, N. Mladenovic, B. Ramos, and J. M. Carvalho, "Skewed general variable neighborhood search for the location routing scheduling problem," *Computer and Operation Research*, vol. 61, pp. 143–152, 2015.

[11] F. Glover, "Future paths for integer programming and links to official intelligence," *Computer and Operation Research*, vol. 5, pp. 549–553, 1986.

[12] F. Glover, "Tabu search - Part I", *ORSA Journal on Computing*, vol. 1, no. 3, pp. 190–206, 1989.

[13] F. Glover, "Tabu search - Part II", *ORSA Journal Computing*, vol. 2, no. 1, pp. 24–32, 1990.

[14] J. F. Cordeau and M. Maischberger, "A parallel iterated tabu search heuristic for vehicle routing problem," *Computer and Operation Research*, vol. 39, pp. 2033–2050, 2012.