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A solution approach for solving the location routing problem of the central rubber market

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Abstract

At present, the central rubber market system is still inefficient, especially when it comes to aspects of the difficulty of transportation for certain rubber sellers moving their wares to the central rubber market, because their plantations are far from the central market, and in addition, rubber selling prices are unfair. Therefore, the researchers have designed an algorithm by applying Tabu Search to find the solution to solving location selection problems of rubber purchasing depots replacing the central rubber market and managing vehicle routes from it to the rubber purchasing depot, where the owner must be a member of the Office of Rubber Replanting Aid Fund (ORRAF) or of the Rubber Plantation Fund Cooperative. The capacity of the purchasing location is divided into three types, small size (10 tons), medium size (25 tons) and large size (50 tons), with truck capacities of two sizes, namely, 20 tons maximum and 25.5 tons maximum. The testing results found that the selection of appropriate purchasing depots and the management of appropriate vehicle routes consist of establishing purchasing depots at seven points, along with vehicle capacity of less than 25 tons, leading to a minimum cost of 58,110.58 baht/day.

Keywords: Tabu search, Central rubber market, Location routing problem, Office of Rubber Replanting Aid Fund (ORRAF)

1. Introduction

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 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 succeful 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 [1-3].

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

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

Order	Seller	Latitude	Longitude	Weight kg/year)
1	ORRAF of Kong Ra, A.Khlong Hoi Khong,Songkhla	06 55 40.77	100 26 18.37	100,404
2	Farmer group, A.Tamot, Phatthalung	07 20 22.15	100 06 47.44	7,658
3	ORRAF of Thungmaipak, A.Cha-uat, Nakhon Si Thammarat	07 54 23.72	99 56 17.27	144,096
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
248	T. Leamsom, A. Palian ,Trang	07 17 39.45	99 45 44.25	171,646
249	T. Udicharoen, A. Khuan Kalong, Satun	06 54 48.14	99 56 07.20	2,278

Table 2 Transportation distance of rubber seller location

Coordinate	D1	D2	D3	…	...	D248	D249
D1	0	69.3	142	…	...	172	98.9
D2	69.3	0	78.7	…	...	108	103
D3	142	78.7	0	…	...	109	171
.	.	.	.	…	...	.	.
.	.	.	.	…	...	.	.
D248	172	108	109	…	...	0	66.1
D249	98.9	103	171	…	...	66.1	0

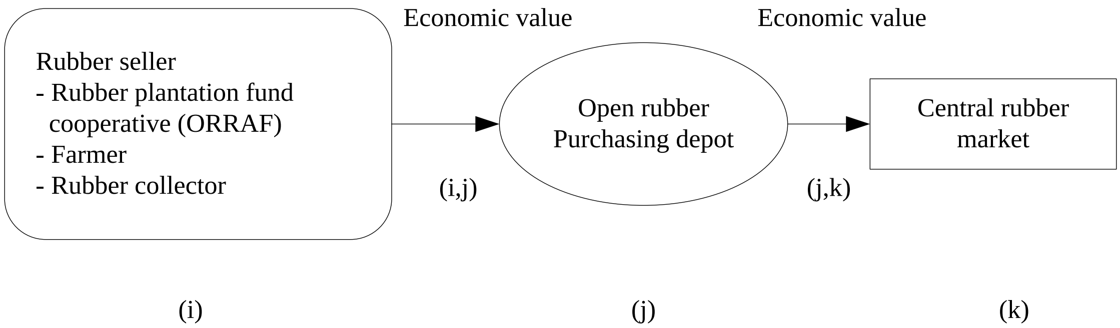

Figure 1 The research concept frame

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. 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 were 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 Rubber Plantation Fund Cooperative (ORRAF) consisting of 66 persons. The procedure is as follows:

2.1 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. 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.

The conceptual framework of this study is made up of the rubber sellers (agricultural cooperative ORRAF, farmers and rubber collectors), rubber depots, selecting their optimum locations, allocating sellers to rubber depots considering economic costs, transporting the rubber to the central market, and managing vehicle routing taking into account economic costs as shown in Figure 1.

2.2 Mathematical model

The mathematical model includes the objective function, various constraints, definition of indexes, variables and related assumptions together with the description of individual constraints in order to understand the feature of the facility location selection and the vehicle routing management of the central rubber market. This model is applied in a computerized program to discover further solutions.

2.2.1 Index

- i, j is the index of node for rubber depot; i and j are in the set N = {1, 2,…,n}
- k is the index of vehicle used for rubber transport; k is in the set K = {1, 2,…k}
- L is the index of node for depot and rubber seller; l is in the set M = {1, 2,…1} and $N \subset M$

2.2.2 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)

2.2.3 Support decision variable

- P is the number of rubber depots
- u_{ik} is the support variable for sub tour

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

2.2.4 Decision variable

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

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

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

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

2.2.5 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.

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

2.2.6 Constraints

$$P = \left\lceil \frac{\sum_{j=1}^{M} q_j}{T_c} \right\rceil \quad (2)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 3 The designation of related parameters for Tabu search

Order No.	Parameter	Value
1	Tabu Size	100
2	Candidate List Size	1,000
3	Max Repeat Best	2,000
4	Max Iteration	10,000
5	Time Computation Seconds	100
6	Random Constructive	Random

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

Table 4 Results of the solution using Tubu search in each case

Case	Number of depots (points)	Distance of clustering (km)	Number of tracks (items)	Routing distance (km)	Total Distance (km)
1	16	6,909.9	8	1,195.2	8,105.1
2	16	7,071.9	8	1,181.8	8,253.7
3	7	8,447.0	8	1,055.1	9,502.1
4	7	8,415.5	7	809.9	9,225.4
5	4	10,463.0	8	847.4	11,310.4
6	4	10,401.4	7	766.7	11,168.1

Table 5 Total cost of location selection and routing management of each case

Case No.	Depot depreciation /day	Delivery cost of the seller (baht)	Transport cost of truck (baht)	Total cost (baht)
1	547.95	27,639.6	42,562.76	70,750.31
2	547.95	28,287.6	34,719.07	63,554.62
3	479.45	33,788.0	37,997.44	72,264.89
4	479.45	33,662.0	23,969.13	58,110.58
5	547.95	41.852.0	30,218.20	72,618.15
6	547.95	41,605.6	22,532.85	64,686.4

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 s_{ik} 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.

2.3 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 [11-16], 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 cust**o**mers (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.

3. Result

Tabu search was applied to find the solution for facility location problems combined with vehicle routing problems of the central rubber market by defining 3 depot capacities as small size (10 tons), medium size (25 tons) and large size (50 tons), and the truck capacity was divided into two types as 20 ton size and 25.5 ton size. Therefore, it could be experimented in six cases: (1) depot capacity of less than 10 tons along with truck capacity of up to 20 tons, (2) depot capacity of not more than 10 tons with truck capacity of less than 25.5 tons, (3) depot capacity of not more than 25 tons with truck capacity of less than 20 tons, (4) depot capacity of less than 25 tons with truck capacity of less than 25.5 tons, (5) depot capacity of less than 50 tons and truck capacity of less than 20 tons, and (6) depot capacity of less than 50 tons with truck capacity of less than 25.5 tons. The number of testing cycles of each case is given at 30 times to determine the minimum sum of distances. The best solution of each case can be seen in Table 4.

After purchasing depots and vehicle routes had been realized, as seen in Table 4, the sum of costs of each case were compared, which included depreciation of the depot, the delivery cost of the seller and the transportation cost of the trucks, as can be seen in Table 5.

Table 5 shows that the minimum cost in the case of depot capacity of less than 25 tons combined with truck capacity of not more than 25.5 tons.

4. Conclusions

The solution search was divided into two parts: the first part was finding initial solutions by randomization and the second part was neighborhood search, consisting of five methods: (1) Exchange depot inside group, (2) Swap move customer 1: 1, (3) Insert One-Move, (4) Swap Move Customer Many to Many, and (5) Chain Insert One-Move. The C # computerized language was written to assist solution search. The testing result signified that the purchasing depot selected should have a depot capacity of not more than 25 tons along with vehicle loading of less than 25.5 tons. The 7 depots included (1) Tamot farmer group with a capacity of

24,199 kgs, (2) ORRAF, Kong Ra with a capacity of 24,347 kgs, (3) Rubber Fund Cooperative Satun with a capacity of 16,003 kgs, (4) ORRAF, Saphan MaiKaen with a capacity of 18,019 kgs (5) ORRAF, Lam Plai Phatthana with a capacity of 22,834 kgs, (6) ORRAF, Nong Bua with a capacity of 23,047 kgs, and (7) ORRAF, Thung Don with a capacity of 24,742 kgs, by using 7 trucks at a sum of 58,110.58 baht/day.

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