The Selection of the Network Marketing Locations and Vehicle Routings for Rubber Transportation in the Lower Southern Region of Thailand

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Abstract. *For rubber transportation process, the farmers or rubber sellers usually deliver their whole raw rubber products to sale the central rubber markets. This could cause high transport costs; especially, those who are away from the markets. This research presents a method to reduce these costs by selecting the proper network market locations and vehicle routings for rubber delivering for the lower southern region of Thailand was considered, which currently had 503 sellers and 2 central rubber markets. The solution was divided into 3 sub-methods. The first sub-method is to initiate solution by using K-mean clustering method. The second sub-method is the algorithm to solve the vehicle routing. The last sub-method is the optimization improved with Adaptive Large Neighbor Search (ALNS). The analytical results revealed that there were 12 appropriated locations including 2 locations with the unlimited capacities, the small network markets are 7 locations, the large network markets are 3 locations. The total delivery cost was 227,231.73 baht per day.*

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1. Introduction

Rubber is one of the most important economic plants of Thailand. Several supports and politics have been continuously provided by the government regarding productions, processes, exports and other aspects [1]. Accordingly, the number of the rubber sellers and farmers in all parts of the country is increased [2]. Thus, the rubber yields of the country are increased quickly [3]. According to the data of the Rubber Research Institute in 2017 [1], it was found that the southern part had the biggest area of the rubber seller and farmer of 14,579,285 farms (63.35 %).

It was followed by the northeastern part (21.25%), the eastern part (9.7%), the northern part (3.8%) and the central part (1.91%), respectively.

Additionally, 87.5% of the rubber production is exported, while 12.5% is consumed domestically. Most of the rubbers are exported in the forms of rubber sticks, smoked rubber sheets, concentrated latex, and rubber gloves. Furthermore, rubber woods are processed into processed woods and particle boards in order to produce furniture and parts. The main export markets of Thailand are China, Malaysia, Japan and the United States of America.

Since the demands on the rubbers and the areas of the rubber sellers and farmers in Thailand are increasing, the Ministry of Agriculture and Cooperatives values generating incomes and securing the well-being of farmers and gardeners by establishing the central rubber markets in various parts including Yala Central Rubber Market, Songkhla Central Rubber Market, Nakhon Si Thammarat Central Rubber Market, Surat Thani Central Rubber Market, Buriram Central Rubber Market and Nong Khai Central Rubber Market in order to have the centers for efficiently collecting and distributing the rubbers to buyers [2].

Actually, the local market systems significantly affect the rubber markets. That is, most rubber gardeners sell the rubbers through the local markets that are the rubber shops in the villages, sub-districts and districts with many rubber seller and farmer. The rubbers are sold through middlepersons [4],[5]. Consequently, the gardeners are taken advantage of and their selling prices are unfair. In some cases, the gardeners have the low amounts of rubbers that are not worthwhile investment because of the transportation costs.

On the other hand, if some rubber gardeners have high amounts of rubbers, then only one pickup truck with the maximum payload capacity of three tons will not be enough for only one trip to transport the rubbers. This is the cost that reduces the expected incomes of the rubber gardeners. Hence, this study focuses on selecting the network marketing locations and vehicle routing from each seller in each sub-district by following the principles of the network marketing similarly to the central rubber markets.

In this study, the problems of the selection of the network marketing locations and vehicle routing by selecting the routes in the lower southern part with the biggest area of the rubber sellers and farmers in seven provinces including Pattani, Yala, Narathiwat, Songkhla, Phatthalung, Trang and Satun were solved by the researcher(s). It was expected the study would increase the incomes of the rubber gardeners and decrease the fuel costs.

2. Relevant Studies

The problems of the selection of the network marketing locations and vehicle routing are NP-hard problems, due to the characteristics of the problem being complicated and the fat that the problem, LINGO may be unable to solve it. The purposes of the selection of the network marketing locations and vehicle routings are to minimize costs including buying point establishment costs, transportation costs, network marketing depreciation costs and vehicle depreciation costs. There were many researchers studying location routing problems (LRPs). Somsak [6] studied the problems of the selection of locations and transport routing of the central rubber markets by applying Tabu search method. According to the findings, it was found that there were 16 buying points with the capacity of 10 tons. There were two sizes of vehicles: four 10 wheel trucks and one 10 wheel trailer. The total cost was 53,313.89 baht/day. Yang-Byung Park and et. al. [7] applied the genetic algorithm (GA) to solving the LRP about obsolete inventory. The number and locations of the warehouses as well as the inventory levels were specified. It was found that the mentioned method provided the appropriated answer(s) within the short time period(s). Yu V.F. and Lin S.Y. [8] studied the selection of the locations and transport routing by applying the simulation annealing (SA) heuristic to solve the problems with 318 customers. It was found that SA could efficiently solve the problems. Hossein Asefi and Samsung Lim. [9] presented the guidelines for managing the wastes in the community (ies) with the problems of the selection of the locations and transport routing in order to lower the waste disposal costs. It was found that SA was efficient. Vincent F.Yu. et al. [10] presented the solutions for solving the problems of the selection of the locations and transport routing for establishing the product distribution center(s). The vehicle was the capacity of each location. It cannot return to the product distribution center(s) after providing the services for the customers. The purpose was to minimize the costs including the establishment costs, vehicle costs and transportation costs. It was found that there were four buying points. It was found that SA could provide the efficient solutions for the mentioned problems. Moreover, SA and greedy method were applied by Novita Hanafiah et al. [11] in order to make the plans for the tourists. The experimental results showed that the improved SA algorithm could improve the efficiency of travelling to the places by the tourists. Houda Derbel et al. [12] presented the problems of the selection of the locations and transport routing with the various capacities of the buying points and the unlimited number of the trucks by applying GA and the iterative local search (ILS). It was found that the mixed method could solve the problems more efficiently than Tabu method.

It is necessary that the researchers should develop and improve the solutions in order to obtain the optimal cost reductions or best profits. The adaptive large neighborhood search (ALNS) by Ropke S.and Pisinger D.[13] was widely applied. Vinicius Gandra et al. [14] presented solving the gate matrix layout problem (GMLP) by identifying the components of the electronic circuits in order to minimize the circuit welding points. The mentioned study applied ALNS to solving GMLP. The experimental results showed that ALNS could provide efficient solutions (89%). Regarding transportations and logistics, unmanned aerial vehicles or drones were used by David Sacramento. et al. [15]. The drones could significantly reduce the operating costs of the routes and the fuels used by the trucks. In this study, there were mathematical models similar to the travelling salesman problem. However, many trucks had limited capacities and times. To minimize the costs, ALNS was applied. According to the test results, it was found that replacing the trucks by the drones could shorten the operating times. Chen S. et al. [16] studied the problems about dynamic vehicle routing with ALNS. The limitations were the limited vehicles and windows hard to use. The processes of ALNS consisted of the random removal, worst removal, static-related removal and time-related removal. The solutions were repaired with the greedy insertion, regret insertion and noise insertion. By comparing the average transportation time of ALNS and that of other methods was slightly longer than that of the other methods. Nonetheless, the error rate of ALNS was lower than 4.63% by comparing to the other methods. ALNS also had very short time to solve the problems. Chalermchat et al. [17] applied ALNS to solve the problems of the selection of the locations and electric train routing with the limited distances for transporting the agricultural products. It was found that ALNS could provide the optimal solutions within the short time periods.

3. Methodology

For the problems of the selection of the network marketing locations and vehicle routing for transporting the rubbers in the lower southern area of Thailand, there were Songkhla, Trang, Satun, Pattani, Yala and Narathiwat. This included Songkhla Central Rubber Market and Yala Central Rubber Market.

3.1 Data Collection

The geographic coordinates of Songkhla Central Rubber Market and Yala Central Rubber Market, Thailand, as well as the rubber sellers and rubber amounts in 2017 were identified by the researcher(s) as shown in Table 1. The distances between the central rubber markets and rubber sellers were calculated by using the Google Maps. The distances were recorded in the matrix tables with the Microsoft Excel program. The data were verified by the researcher(s) who randomly performed measuring the actual distances between the central rubber markets and ten rubber sellers with the distance meters. It was found that the distances were similar. The error rate was not higher than 10%. The example of the matrices of the distances is shown in Table 2.

Order	Central rubber market/Seller	Quantity (kg/day)
1	Songkhla central rubber market	-
2	Yala central rubber market	-
3	Kantang, Kantang, Trung	1,178
4	Kantangtai, Kantang, Trung	2,045
.	…	…
.	…	…
504	Paknam, Langu, Satun	661
505	Lamson, Langu, Satun	1,183

Table 1 Location coordinates and quantity of rubber

Coordinate	D1	D2	D3	…	…	D504	D505
D1	0	6.8	8.4	…	…	106	116
D2	6.8	0	15.9	…	…	113	123
D3	8.4	15.9	0	…	…	102	112
D4	31.4	38.9	37.4	…	…	131	141
.	.	.	.	…	…	.	.
.	.	.	.	…	…	.	.
D504	174	183	175	…	…	0	134
D505	305	313	303	…	…	134	0

Table 2 Transportation distance of rubber seller location

3.2 Mathematical Models

The mathematical models consisted of the functions, conditions, definitions of the indices and variables, relevant hypotheses and descriptions in order to understand the characteristics of the network marketing locations and routes. The models could be applied to computer programming in order to find the solutions.

3.2.1 Index

i,j is the index of node for rubber seller, network market and central rubber market; by j=1 is central rubber market of Songkhla, j = 2 is central rubber market of Yala

k is the index of vehicle

a is the index size of network market

3.2.2 Set

I is set of rubber seller where $I = \{1, 2, \ldots, 505\}$

J is set of open network market where $J = \{1, 2, \ldots, 505\}$

K is set of vehicles where $K = \{1, 2, \ldots, k\}$

A is set of size network market where $A = \{1, 2, 3\}$

3.2.3 Parameters

E_k is the fuel cost of vehicle k (baht per kilometer)

Q_i is the quantity of rubber sold by seller i (ton per day)

D_{ij} is the distance from node i to node j (kilometer)

D^M is the distance transportation not more than 480 kilometers

C_a is the maximum capacity of network market a (ton per day)

M_a is the depreciation of the network market a (baht per day)

F_a is the fixed expenses in the operation of network market a (baht per day)

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

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

B^M is big M

3.2.4 Decision Variable

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

$$y_{ja} = \begin{cases} 1 & \text{if rubber network market is open at node j size of network market a} \\ 0 & \text{otherwise} \end{cases}$$

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

3.2.5 Support Decision Variable

$$v_{jk} = \begin{cases} 1 & \text{if transportation from network market j by vehicle k} \\ 0 & \text{otherwise} \end{cases}$$

$$v_{ij} = \begin{cases} 1 & \text{if transportation from rubber seller i to network market or central rubber market j} \\ 0 & \text{otherwise} \end{cases}$$

W_{ik} = is the Volume rubber at seller i transports by vehicle k

3.2.6 Objective Function

$$\text{Min } z = \left(\sum_{j\in J, j>2}\sum_{a\in A} y_{ja}\left(F_a + M_a\right)\right) + \left(\sum_{i\in I}\sum_{i\in J}\sum_{k\in K} E_k D_{ij} x_{ijk}\right) + \left(\sum_{k\in K} H_k s_k\right) \quad (1)$$

3.2.7 Constraints

$$\sum_{i\in I} w_{ik} \le V_k \quad \forall k \in K \quad (2)$$

$$\sum_{k\in K} w_{ik} = Q_i \quad \forall i \in I \quad (3)$$

$$\sum_{j\in I} x_{ijk} \le 1 \quad \forall i \in I, \forall k \in K \quad (4)$$

$$w_{ik} \le B^M \sum_{j\in I} x_{ijk} \quad \forall i \in I, \forall k \in K \quad (5)$$

$$\sum_{j\in I} x_{ijk} = \sum_{j\in I} x_{jik} \quad \forall i \in I, \forall k \in K \quad (6)$$

$$\sum_{i\in J} z_{ij} = 1 \quad \forall j \in I \quad (7)$$

$$\sum_{a\in A} y_{ja} \le 1 \quad \forall j \in J, j > 2 \quad (8)$$

$$\sum_{i\in I} z_{ij} Q_i \le \sum_{k\in K} v_{jk} V_k \quad \forall j \in J \quad (9)$$

$$\sum_{i\in I} z_{ij} Q_i \le \sum_{a\in A} y_{ja} C_a \quad \forall j \in J, j > 2, \forall k \in K \quad (10)$$

$$v_{jk} \le \sum_{a\in A} y_{ja} \quad \forall j \in J, \forall k \in K \quad (11)$$

$$\sum_{j\in J} v_{jk} \le s_k \quad \forall k \in K \quad (12)$$

$$\sum_{i\in I}\sum_{j\in I} x_{ijk} \le s_k N \quad \forall k \in K \quad (13)$$

$$\sum_{i\in I}\sum_{j\in I} D_{ij} x_{ijk} \le D^M \quad \forall k \in K \quad (14)$$

$$u_{ik} - u_{jk} + 1 \le N\left(1 - x_{ijk}\right) \quad \forall i, j \in I, \forall k \in K, i \ne j \quad (15)$$

$$0 \le u_{ik} \le N \quad \forall i \in I, \forall k \in K \quad (16)$$

$$2 * x_{ilk} \le z_{ij} + z_{lj} + B^M (1 - z_{ij}) \quad \forall i, j, l \in I, \forall k \in K, i \ne l \quad (17)$$

$$\sum_{a\in A} y_{ja} = 1 \quad j \in \{1,2\} \quad (18)$$

$$x_{ijk}, y_{ja}, s_k, v_{jk}, z_{ij} \in \{0,1\} \quad i, j \in I, \forall k \in K, \forall a \in A \quad (19)$$

The objective of function 1 is minimize the costs including the network marketing establishment and operation costs, transportation costs from the rubber sellers to the markets, and vehicle costs. The constraint (2) is that any vehicle must carry the rubbers without exceeding the load capacity. The constraint (3) is the amount of the rubbers loaded from the rubber seller must be equal to the amount of the rubbers of that the rubber sellers have. The constraint (4) is that each vehicle moves to each node on only one in-bound route. The constraint (5) the amount of rubber of the rubber seller i loaded by the vehicle k is transported from any node to the rubber seller i. The constraint (6) is requires that the vehicle arriving at any point must always leave that point. The constraint (7) is that restricts the rubber seller to sell the rubbers to only one market. The constraint (8) is the location of the established network can have only one form or it is not established. The constraint (9) is each market's vehicle capacity must be higher than that of the rubber seller. The constraint (10) is each market's capacity must be higher than that of the rubber seller. The constraint (11) is requires that the established market must have the special vehicle(s). The constraint (12) is each vehicle can be used by only one established market. The constraint (13) is the route can be established only if the vehicle k is used. The constraint (14), is that requires that each vehicle can transport the rubbers within the distance of 480 kilometers per trip. The constraints (15)-(16) are the equations preventing sub-tours. The constraint (17) is that restricts that the transportation must be for the customers in the same market. The constraint (18) is that specifies that 1 is Songkhla Central Rubber Market and 2 is Yala Central Rubber Market. The constraint (19) is the decision making variable can have only two values including 0 or 1.

3.3 Solution Development

The selection market networking locations and vehicle routing, the study had three problem solving steps: Step 1 – the initial solution, Step 2 – The vehicle routing, and Step 3 – solution improvement as described below:

Step 1 the initial solution – The initial two locations were selected (this was because there were two central rubber markets) with the k-means clustering method [18], [19] as follows:

1) Randomly create the K groups of the centroids or markets

2) Randomly add the remaining rubber sellers to the groups with the shortest distances between the centroids and the rubber sellers. The rubber sellers with the amounts of the rubbers higher than the capacities of the markets were not selected. This was called the capacitated clustering method. This addition can change the centroids.

3) Calculate the mean of the new centroids.

4) Repeat these steps until the all rubber sellers are added to and become the members of the groups as shown in Fig. 1.

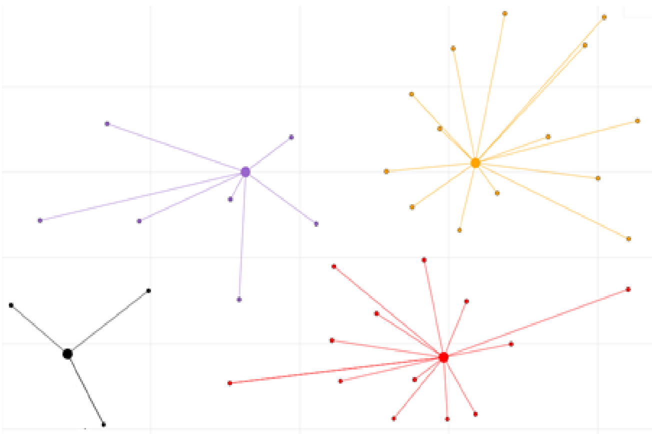

Fig. 1 Initial solution of K-mean clustering

Increase the number of the markets until there are 30 locations by considering the market establishment and transportation costs. Repeat each market establishment process for ten times. Calculate the average cost. It was found that the market establishment tended to keep increasing. The number of the locations with the lowest costs was eight. If the number of the markets was 15 or move, then the market establishment cost tended to increase respectively as shown in Fig. 2.

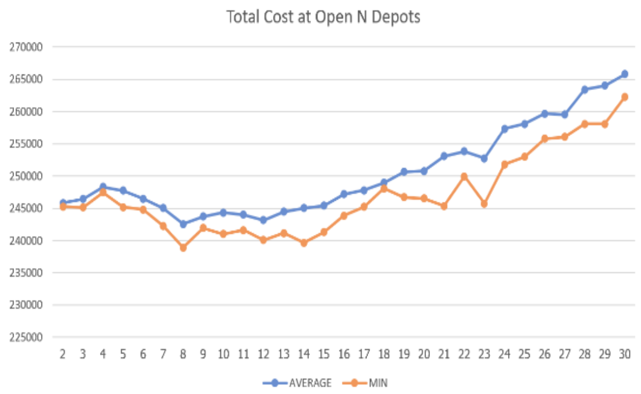

Fig. 2 Cost of opening network market

Step 2 the vehicle routing – vehicle routing: the saving method was used [20]. The routes were set by considering the low market establishment costs. By considering Fig. 2, it was found that there were 8 – 14 locations with the lowest costs. Therefore, the number of the mentioned markets was used for setting the routes with the saving methods as follows. Firstly, the starting point of a market was selected as a node. Secondly, the distance or saving cost was calculated. $S_{ij} = C_{iD} + C_{Dj} - C_{ij}$ where i and j are the sellers and D is the market. Thirdly, the values of S_{ij} were sorted in the descending order. Fourthly, the route was created by linking nodes i and j with the highest values of S_{ij}. Fifthly, the steps were repeated until all routes were set according to the conditions as follows. The trip of each vehicle must load the products not exceeding the load capacity of the vehicle. Each trip duration must not exceed the specified duration as shown in Fig. 3.

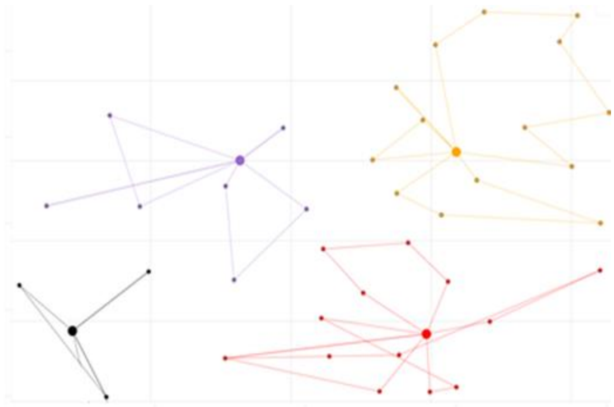

Fig. 3 Vehicle routing by saving method

Step 3 solution improvement–The ALNS was used according to the principles of repairing and destroying the solutions as follows:

1) Adjust the weight of the destroy and repair operators. At the beginning, define the weight of all the destroy and repair operators as equal to 1.

2) Calculate the probability of each destroy and repair operators.

3) Randomize the number of rubber seller based on their degree of destruction and repair. The degree of distruction (d) is used to determine the number rubber seller or farmer removed from the solution. This work designed a specific set of destructive degrees as proportion of 20%, 30%, 40%, and 50%, At each iteration, the destroy operators will randomly select the destructive degree before execution.

4) Randomize a number between 0 and 1 for destroy operators. This work designed five destroy operators.

• Random Removal, the basic concept is to randomly remove rubber seller or farmer and eliminate them from the current solution.

• Worst Removal, the basic concept is the worst solution or that with the highest costs.

• Relate Removal, the connect elimination operator involves destroying rubber seller or farmer that depend on the position of an adjacent point that is connected to the position of a removal point.

• Cluster Removal, this operator has the purpose to diversify of the searching area. The currently selected depot will be changed in its status from opened to closed.

• K-route Removal, the route elimination operators removes an entire route. The new route will be rearranged by a repair operator. This method is a route implovement to explore better solutions

5) Randomize a number between 0 and 1 for repair operators. This work designed three repair operators.

• Greedy Insertion, the greedy repair operator will select the best position by considering the lowest cost and including that in the routes.

• Regret Insertion, the regret repair the solutions by selecting the routes with the lowest costs and including that at the locations with the lowest cost.

• Random Insertion, the random repair operators is the most simple and uncomplicated method. This idea is to increase diversity by re-inserting the removed farmer into any random position.

6) Determine acceptance and stopping criteria by implementing the Simulated Annealing (SA) principle. SA is the most widespread acceptance method used by ALNS algorithm. Every improving solution is accepted. Nevertheless, if Z(s′) > Z(s), s′ is accepted with a probability, as show by Equation (20):

$$p = exp^{\frac{(Z(s) - Z(s'))}{T}} \tag{20}$$

7) Update the solution.

8) Update the weight of the destroy and repair operators and check the number of iterations (n=1,000). The improved results are shown in Fig. 4.

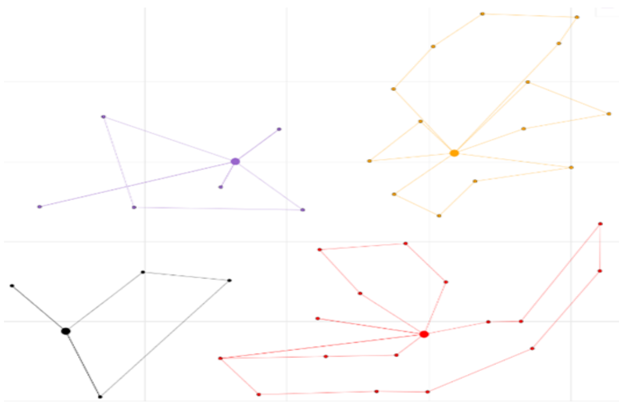

Fig. 4 Improvement method adaptive large neighborhood search

4. Results

The purpose of this research article is to minimize the costs in order to identify the costs of the transportations from the rubber seller to the markets, the vehicle depreciation costs and the market establishment costs by selecting the locations with the k-mean clustering method and routing with the saving method. The solutions were improved with ALNS for selecting the network marketing locations and vehicle routing in the lower southern part of Thailand. The three sizes of the network markets could be established. Firstly, the small markets had the capacity of 50 tons. The establishment cost was 1,000,000 baht. Secondly, the medium markets had the capacity of 100 tons. The establishment cost was 2,000,000 baht. Thirdly, the large markets had the capacity of 200 tons. The establishment cost was 3,000,000 baht. Furthermore, the central rubber markets could be the buying points with the unlimited capacity. The useful life of the buying points was 20 year.

Regarding the rubber transportation costs, the costs were calculated by the rubber sellers according to the distance of each seller at the rate of 4.0 baht per kilometers. The truck depreciation costs were calculated according to the values of the trucks. There were three types of the trucks: (1) the six wheeler trucks had the value of 1,500,000 baht and the load capacity of 10 tons, (2) the ten wheeler trucks with the value of 2,300,000 baht and the load capacity of 20 tons, and (3) the ten wheeler trailers with the value of 3,000,000 baht and the load capacity of 25 tons. The useful life of every type of the trucks was 12 years [2]. By selecting the network marketing locations and vehicle routing, the optimal solutions were obtained as shown in Table 4 and Fig. 5.

Item	Central rubber market/Seller	Size of market	Number of routing	Transport of distance (km.)	Quantity of rubber (kg.)	Total cost (baht)
1	Songkhla Central Rubber market (D1)	Unlimited	45	4,883.37	1,073,578	50,355.40
2	Yala Central Rubber market (D2)	Unlimited	82	9,983.09	1,984,143	96,096.74
3	Bang Pao, Kantang, Trung (D12)	Small	3	389.71	70,120	5,723.22
4	Nayongnuea, Nayong, Trung (D20)	Small	3	171.34	71,599	4,849.74
5	Ban Na, Palian, Trung (D27)	Large	7	409.90	190,725	12,762.89
6	Na Ta Luang, Mueang, Trung (D34)	Small	4	248.62	91,989	5,843.80
7	Bohin, Sikao, Trung (D67)	Small	3	128.84	96,822	4,679.74
8	Khao Khao, Huai Yot, Trung (D70)	Small	4	206.77	90,724	5,676.40
9	Wangkhiri, Huai Yot, Trung (D81)	Small	4	143.30	80,252	5,422.52
10	Don Sai, Khuan Khanun, Phatthalung (D275)	Small	4	282.95	93,060	5,981.12
11	Khuha Sawan, Mueang, Phatthalung (D309)	Large	8	798.70	183,517	15,003.02
12	Tha Phae, Tha Phae Satun (D481)	Large	8	757.23	184,019	14,837.14
		Total	175	18,403.82	4,210,548	227,231.73

Table 4 Cost for network marketing location and vehicle routing

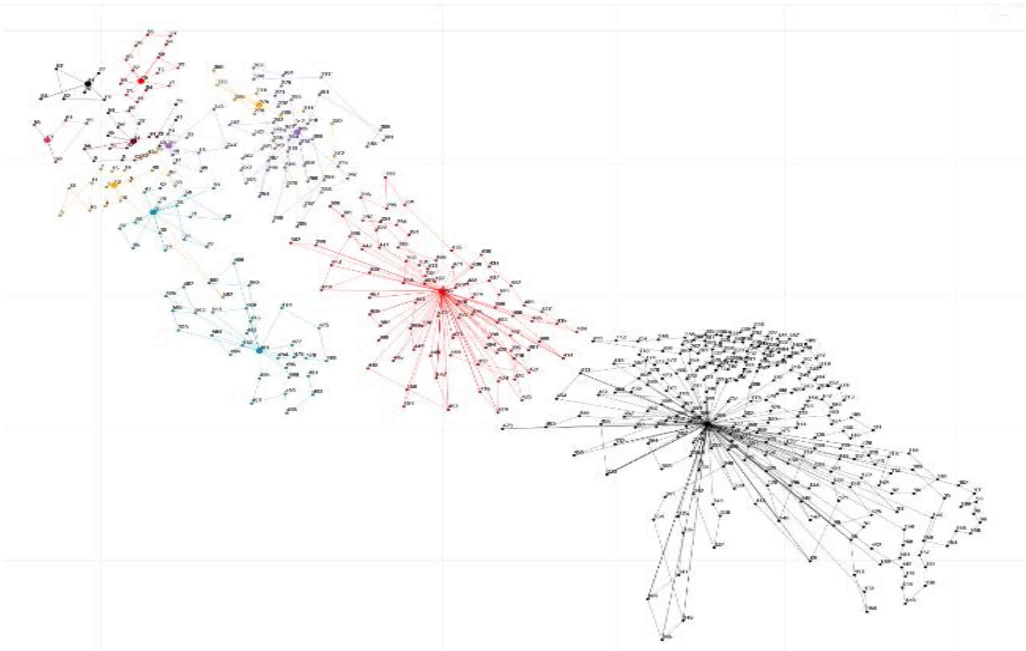

Fig. 5 Position of network marketing location and vehicle routing

5. Conclusion

In this study, the selection of the network marketing locations and vehicle routings for rubber transportation in the lower southern region of Thailand has been proposed. The locations were selected with the k-mean clustering method and the routes were set with the saving method. Then, the solutions were improved with ALNS for selecting the network marketing locations and vehicle routing in the lower southern part of Thailand in order to minimize the costs. There were the 503 sellers and the two central rubber markets including Songkhla Central Rubber Market and Yala Central Rubber Market. To find the solutions, there are the three parts. The first part was the k-mean clustering method. The second part was the saving method. The third part was ALNS.

It was found that there are the 12 selected locations: 1) Songkhla Central Rubber Market with the unlimited capacity and 45 routes; 2) Yala Central Rubber Market with the unlimited capacity and 82 routes; 3) the market in Bang Pao Sub-District, Kantang District, Trang Province with the low capacity and three routes; 4) the market in Na Yong Nuea Sub-District, Na Yong District, Trang Province with the low capacity and three routes; 5) the market in Ban Na Sub-District, Palian District, Trang Province with the high capacity and seven routes; 6) the market in Na Ta Luang Sub-District, Mueang Trang District, Trang Province with the low capacity and four routes; 7) the market in Bohin Sub-District, Sikao District, Trang Province with the low capacity and three routes; 8) the market in Khao Khao Sub-District, Huai Yot District, Trang Province with the low capacity and four routes; 9) the market in Wang Khiri Sub-District, Huai Yot District, Trang Province with the low capacity and four routes; 10) the market in Don Sai Sub-District, Khuan Khanun District, Phatthalung Province with the low capacity and four routes; 11) the market in Khuha Sawan Sub-District, Mueang Phatthalung District, Phatthalung Province with the high capacity and eight routes, and 12) the market in Tha Phae Sub-District, Tha Phae District, Satun Province with the high capacity and eight routes. The lowest total cost was 227,231.73 baht per day.

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