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# Metaheuristic For Solving the Location Routing Problem of the Biomass Power Plant

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**Abstract**

This research aims to solve the location routing problem of the biomass power plant. The objectives of the research are to determine (1) number and location selection of power plants that suitable to spatial biomass volume (2) the minimize cost of transportation routing of raw materials delivery to power plant and (3) exploring the figure of the minimize total cost. Research implementation started from metaheuristic algorithm and applied to find the results by using random selection neighborhood methods of tabu search technique. The testing data was collected in Songkhla province, Thailand. The research found that six locations in Songkhla are suitable to set up the biomass power plant. The six suitable locations comprise of (1) The second location in Tunglan sub-district, Klonghoikhong district (2) The twenty-seventh location in Sadao sub district, Sadao district (3) The thirty second location in Thapo sub district, Sadao district (4) The forty first location in Chalung sub district, Hatyai district (5) The sixty ninth location in Natawee sub district, Natawee district (6) The eighty fifth location in Khaodaeng sub district, Sabayoy district. The figure of transportation cost is 15,233.66 baht per day while the total operation cost is 662,496.6 baht per day.

**Keywords**: Location Problem, Vehicle Routing Problem, Biomass Power Plant

## INTRODUCTION

Electricity production from renewable energy such as biomass is one of policy that is allocated in electric production capacity development plan of Thailand in 2015 – 2036[1] to respond the mission which to provide enough energy to electric demand of Thailand. Such electric production from renewable energy policy of the government aims to solve the generally social problems such as commune waste problem and agricultural abundant products which has the strategy to promote bioenergy namely energy from waste, biomass and biogas are the first priority. For biomass potential in Thailand found that the remaining potential could produce electricity 2,500 megawatt by estimate. From biomass electric production summary report of Thailand in 2014 found that the production capacity is 2,541.8 megawatts and within year 2036, the goal is set to be 5,570 megawatts.

Although Thailand has high biomass potential, to apply the biomass to produce the electricity is still has problems and obstacles such as the biomass that has so many but they are scatter which make difficulty to collect such as sliver, slab, rubber tree root, sawdust which being in the ranch and farm. The biomass amount which sent to factory and nearby area is not enough to produce electricity. So we must find the other kinds of biomass from other sources to supply the power plants. The transportation cost will occur, the further the source is, the higher in transportation cost is occur. Thus, to take biomass to produce electricity, it has to implement two important parts which are 1) power plant location selection 2) raw material transportation route to the power plant. These two parts are strategic decision factors that effect to worthiness of business.

Thailand has enormous volume of rubber planting area which is counted in the second place of the world next below Indonesia. [2] The rubber planting area in 2014 is 8,765,499.60 acres [3] The rubber planting area scatter in different parts of Thailand especially in Songkhla province which has plant volume at 815,267.19 acres that is the second place in Thailand next below Suratthani province with 1,041,064.03 acres. Meanwhile the rubber trees which over 20 age years often yield latex lower than standard, and the agriculturists have to cut them down and plant the new ones to compensate. These old rubber trees are agricultural abundant biomass products. The cutting down 0.395 acres of rubber trees can give 3 tons of sawdust, 12 tons of slab and sliver and 5 tons of roots, totally, 0.395 acres of rubber tree cutting down can give 20 tons of biomass. [4] So using the biomass from rubber tree as a raw material to produce electricity is another way to respond the renewable energy electric production policy. So this research is the beginning to develop method to find the amount of rubber wood biomass power plant that suitable with potential of areal biomass, find the location of power plant and raw material transportation routing from raw material resources to each power plants by apply to find the results by using tabu search technique which use the actual data of Songkhla province as the case study.

## LITERATURE REVIEW

Location routing problem could separate into two problems which are Location Problem (LP) and Vehicle Routing Problem (VRP).

**The location problem, generally is the NP-hard problem [5], has 4 specific characteristics namely (1) customer has certain location, (2) factory that want to find the location, (3) the location which customer and factory site on and (4)**

**the distance or time to travel between factory and customer. [6] Besides, Owen and Daskin[7] had divided problem characters as target equation into three types namely covering problem, median or average distance problem and center problem as the example.**

***Location problem in case of specific number of establishment amount P unit.***

Location problem of distribution center or point of purchase amount P unit (P-Median Problem) which was developed for the first time in 1964 by Hikimi [8] is to find the location of distribution center amount P unit (P-Median) by giving weight the distance in network of goods demand point, n point, to let the distribution center delivery or receive goods from customer which has both limitation resource (Capacitated P-Median) and non-limitation of resource (Uncapacitated P-Median) distribution center.

P-Median distribution center is the problem which has the location selection of distribution center amount P unit within the amount of customer n unit include to make a decision that selected distribution center will deliver the goods to any customers by setting the total transportation distance of every distribution centers to every customers in the shortest distance. Osman and company[9] conclude that the location problem which has limitation of resource (Capacitated P-Medians Problem ; CPMP) is the special type of distribution center location selection which similar to P-Median Problem but it concentrate in delivery capacity, limit of goods of distribution point and customer demand also.

**Vehicle Routing Problem (VRP)**

The vehicle routing problem is the NP-Hard Problem which the first presented in the research of Dantzig and Ramser [10], Golden and company[11], after that many researchers interested in VRP solving method development. The interested VRP have been added other limitation issues as case studies or actual events in everyday life such as receive - delivery time limitation (Vehicle Routing Problem with Time Window), in the case of receiving and delivery time is coincident[12], and the transportation distance may has known or unknown value character, for example. Besides, the researchers which have the important role in VRP development such as Golden et.al (1977) [13], Christofides et.al [14], Laporte et.al [15], Toth and Vigo [16] and Kytojoki et.al [17].

2.3 In addition, there are some relevant researches that have been used to solve the problem of location selection and raw material transportation routing e.g. Glover [18], presents the results of applying a tabu search technique to solve the problem and concluding that a tabu search technique is a good estimation technique for mathematical calculations when comparing to other techniques, Taillard, E [19] has proposed a tabu search technique for VRP time window problem. Thangiah, SR [20] has proposed a method of combining simulated Annealing (SA), Genetic Algorithm (GA) and (Tabu Search: TS) in order to solve the problem. VRP, Sicilia et al. [21] presented the method of Neighborhood Search and Tabu Search in solving transport problems.

**METHODOLOGY**

Research implementation start from problem characteristic studying, theories and related researches studying, related data collection, mathematical model design and development, finding the result by Lingo Program and research conclusion.

**Data Collection and Analysis**

***Rubber wood biomass potential data in Songkhla province between March 2014 to the end of February 2015 show in Table 1.***

**Table 1** The example of biomass volume summary in each area.

| No. | Raw Material Resource or Supplier | Volume (Tons/Day) |
|---|---|---|
| 1 | Khlonghoykhong sub district, Khlonghoykhong district | 78.224 |
| 2 | Thoonglan sub district, Khlonghoykhong district | 47.890 |
| … | … | … |
| 87 | Thankhiri sub district, Sabayoy district | 11.841 |
| Total | | 1,836.898 |

***Biomass sub district position coordinates data collection by using GPS machine: Garmin eTrex 20 and Google Maps Program simultaneously create distance data between each sub districts as show in Table 2.***

**Table 2** The distances between each sub districts.

| Coordinate | D1 | D2 | … | D86 | D87 |
|---|---|---|---|---|---|
| D1 | 0 | 21.9 | … | 172.0 | 98.9 |
| D2 | 21.9 | 0 | … | 108.0 | 103.0 |
| … | … | … | … | … | … |
| D87 | 98.9 | 103.0 | … | 95.6 | 0 |

***Electric wiring cost estimation between the location of power plants that expect to establish to the main wire of Provincial Electricity Authority (PEA) in each 87 area units as show in Table 3.***

**Table 3** The example of electric wiring cost in each area.

| No. | Raw Material Resource or Supplier | Electric Wiring Cost (Baht) |
|---|---|---|
| 1 | Khlonghoykhong sub district, Khlonghoykhong district | 6,017,693.00 |
| 2 | Thoonglan sub district, Khlonghoykhong district | 513,705.50 |
| … | … | … |
| 87 | Thankhiri sub district, Sabayoy district | 17,260,504.80 |

*Power plant establishing cost and raw material transportation cost.*

The power plant establishing cost is calculated as the 9.5 megawatts power plant which cost 787 million baht. Raw material transportation cost is calculated at 4 baht per kilometer.

Mathematical Model Specification

**Index**

i,j is the position index of all nodes of raw material sellers (suppliers) and power plant (depot)

N is the set of suppliers and power plant sequence N = {1,2,...,n} which i and j are member of N.

I is the set of integer {0,1,2,3,...,}

**Parameters**

C is transportation cost (Baht/Km).

$d_{ij}$ is the distance from supplier i to power plant(depot) j (km)

$d_{ji}$ is the distance from power plant(depot) j to supplier i (km)

F is the power plant establishing cost (Baht/Plant).

$g_i$ is raw material volume which supplier i could supply (Kg/Day).

$h_j$ is electric wiring cost from power plant j to main wire of Provincial Electricity Authority (PEA) (Bahts/Plant).

V is the maximum capacity loading of transportation vehicle (Kg/vehicle).

$T_{min}$ is the minimum amount of raw material which power plant (depot) demand (Kg/Day).

$T_{max}$ is the maximum amount of raw material which power plant (depot) can get (Kg/Day).

**Decision Variable**

$$x_{ij} = \begin{cases} 1 & \text{if transportation from i to j.} \\ 0 & \text{in other cases.} \end{cases}$$

$p_i$ the amount of round which vehicle go to receive raw material at supplier i in the direct shipping model whereas $p_i \in I$

$y_j$ is 1 if position j is chosen to be the location of power plant.

**Support Decision Variable**

$r_i$ is raw material weight which leftovers from direct shipping model transportation which supplier i

$u_i$ is for Sub-tour correcting.

$$z_{ij} = \begin{cases} 1 & \text{if transportation from i to j.} \\ 0 & \text{in other cases.} \end{cases}$$

**Sign Function**

$$sign(x) = \begin{cases} 1 & x > 0 \\ 0 & x = 0 \end{cases}$$

Sign function will give value as 1 when x get value more than 0 or the volume occur but if value of x equal to 0 which mean no volume, sign function will give value as 0. This sign function use to indicate the volume having of x value.

**Objective Function**

$$\text{Min Z } C\left(\sum_{i\in N}\sum_{j\in N} d_{ij}x_{ij} + \sum_{i\in N} p_i\left(\sum_{j\in N} Z_{ij}(d_{ij}+d_{ji})\right)\right) + F\sum_{j\in N} y_j + \sum_{j\in N} h_j y_j \qquad (1)$$

**Constraint**

$$\sum_{j\in N} z_{ij} = 1, \forall i \qquad (2)$$

$$\sum_{i\in N} g_i z_{ij} \geq y_j T_{min}, \forall j \qquad (3)$$

$$\sum_{i\in N} g_i z_{ij} \leq y_j T_{max}, \forall j \qquad (4)$$

$$g_i = p_i V + r_i \text{ ,} \forall i \qquad (5a)$$

$$0 \leq r_i < V \text{ ,} \forall i \qquad (5b)$$

$$\sum_{j\in N} x_{ij} = (1 - y_i)\, sign(r_i) + y_i k_i, \forall i \qquad (6)$$

$$\sum_{j\in N} x_{ij} = \sum_{j\in N} x_{ji} \text{ ,} \forall i \qquad (7)$$

$$(1 - y_i)(1 - y_j)(u_i - u_j + V x_{ij}) \leq V - r_j, \quad \forall_i, \forall_j \quad i \neq j \qquad (8a)$$

$$u_i (1 - y_i) \leq V \qquad (8b)$$

$$r_i (1 - y_i) \leq u_i \qquad (8c)$$

$$x_{il} \leq \sum_{i\in N} z_{ij} z_{lj} \text{ ,} \quad \forall_i \forall_{l\in N} \quad i \neq l \qquad (9)$$

$$x_{ij} \in \{0, 1\} \quad \forall_i, \forall_j \qquad (10a)$$

$$z_{ij} \in \{0, 1\} \quad \forall_i, \forall_j \qquad (10b)$$

$$y_{ij} \in \{0, 1\} \quad \forall_j \qquad (10c)$$

$$p_i \in I \quad \forall_i \qquad (10d)$$

The objective equation (1) to find the minimize total cost of Power plant establishing cost, raw material transportation cost and transmission line cost.

Equation (2) is constraint that the raw material from source i must deliver to power plant j only

Equation (3) is constraint that each power plant must receive raw material higher or equal than the specific minimum volume

Equation (4) is constraint that each power plant must receive raw material lower or equal than the specific maximum volume

Equation (5a and 5b) is constraint that quantity of raw material from source i equal to total weight of full truck load multiplied by the number of transport trips (kilogram) with leftover raw material at the supplier, the rest of the raw materials must be less than the capacity of the truck.

Equation (6) is constraint that the sum of outgoing transportation equal to 2 methods (1) if source i has been selected to set up the power plant (yi =1) it will has several outgoing transportation equal to ki (2) if source I has not been selected to set up the power plant (yi =0) the delivery will be made in case there is the raw material leftover (7) is constraint that incoming delivery equal to outgoing delivery. Inequality (10a-10c) is an inequitable binary decision variable (10d) defines a direct shipping cycle where I is an integer.

## Assumptions and Problem characteristics

1) The simulation modeling of location selection and raw material routing problem can be clarified by the designed algorithm and to get the position of raw material source.

2) The source of raw materials is 87 sources, the raw materials from each source can be sent to the power plant one to one only. This result was from the designed algorithm.

3) The mathematical model of the power plants can be obtained from only 87 sources.

4) It defined for capacity of power plant at 9.5 megawatts only.

5) Mathematical modeling of truck routing defined that the suitable capacity is a 10-wheel truck (with a maximum capacity of 20 tons).

6) All the biomass that needs to be delivered to the power plant is the routing of the vehicle, starting from the power plant to receiving raw materials from the designated raw materials. This answer is from the designed algorithm.

7) No Time Window or Post-Delivery Order

8) Adequacy of vehicles at specified capacity of raw material transportation.

9) Provided the exact number of raw material quantity.

10) There is no limit on the maximum distance traveling in each route.

## Testing of mathematical model

Using with Lingo 11 and Window 8.1 Intel (R) Core(TM) i7-4700HQ CPU@2.4GHz Ram 4.00 GB , the result is as per table 4

**Table 4** the result of testing of mathematical model

| Number of supplier (Unit) | Result from Lingo 11 | |
|---|---|---|
| | Time | Status |
| 6 | 0:00:07 | Global Optimal |
| 8 | 0:01:46 | Global Optimal |
| 10 | 0:02:04 | Global Optimal |
| 12 | 10:03:10 | Global Optimal |
| 14 | 24:00:00 | Feasible |
| 16 | 24:00:00 | Feasible |
| 18 | 24:00:00 | Feasible |
| 20 | 24:00:00 | Feasible |
| 40 | 67:21:30 | Unknown |
| 87 | 83:41:18 | Unknown |

Based on test results, the mathematical model is well-established and suitable with a small case not more than 12 suppliers. To use with 87 suppliers, the model was not applicable. Therefore, the tabu search of Meta-Heuristic had been applied to find to answer.

## Tabu search algorithm

Tabu search procedure is per following steps:

**Step 1** To initialize solution with permutation to get the best solution. **Step 2** To use random selection neighborhood in order to get the candidates list at N choice. **Step 3** Dividing 2 candidate solutions, they are tabu candidate solutions and non-tabu candidate solutions. Explore the best answer of 2 solutions to get the best non-tabu solution and best tabu solution.

**Step 4** Checking if the best non-tabu solution is better than the best solution. 1) If so, move forward to step 6. 2) If not, move to step 5. **Step 5** Aspiration by checking if the best tabu solution is better than the best solution. If so, move forward to step 7. **Step** 6 Update tabu list **Step** 7 Checking if tabu is terminated by considering max iteration or if the solution is not be max repetition best solution. In case, either of the solution is real then go to step 8. If not, back to step 2. **Step** 8 End

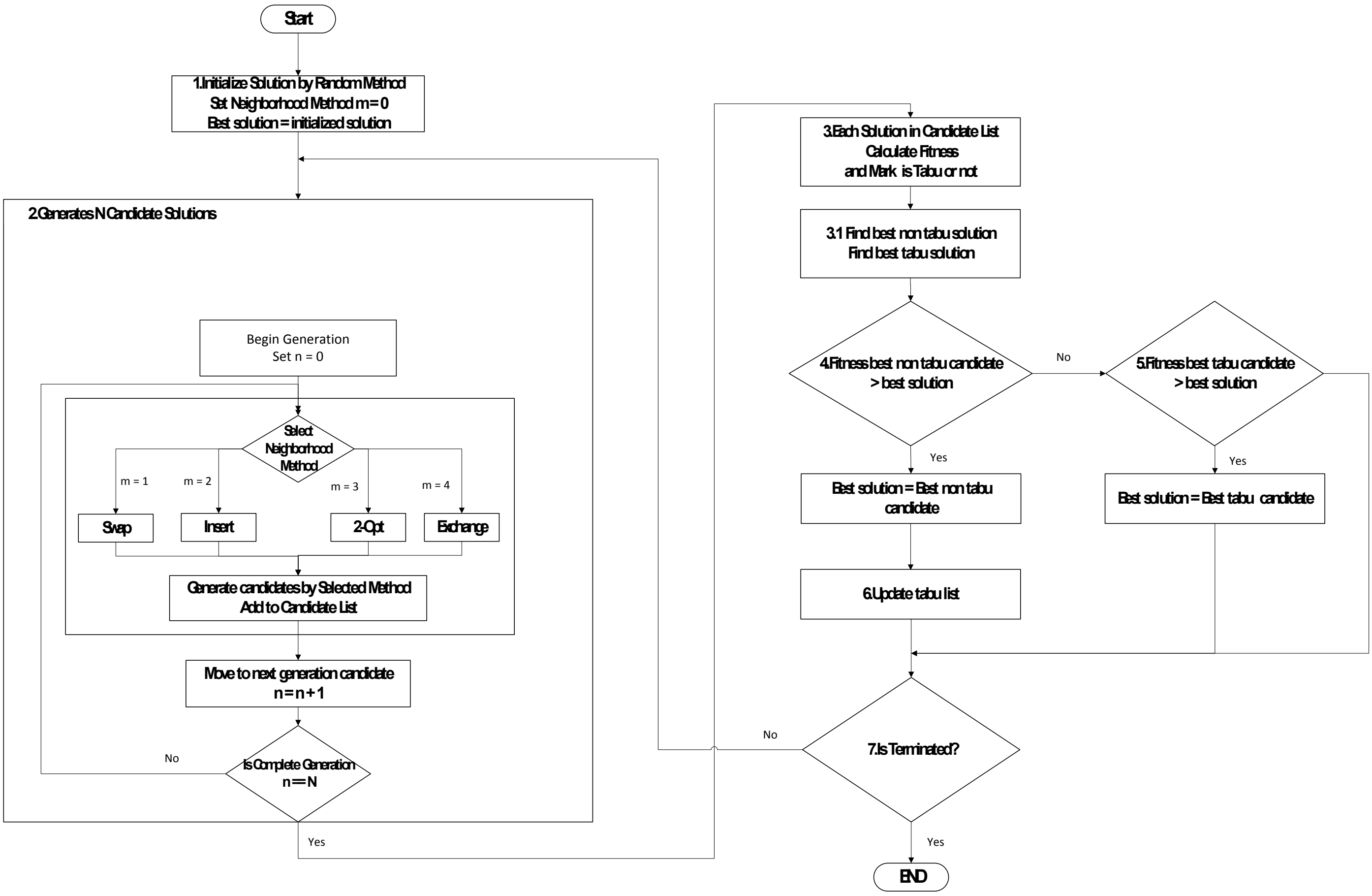


**Figure 1** Flowchart of Tabu search algorithm

### *Parameter of tabu search*

The experimental design had been done by Minitab program with general full factorial design function. To consider 2 parameters that directly affect the tabu search algorithm, they are the sizing of tabu Size; X1 and the size of the answer of candidate list size; X2. The level of parameters used in the experiment had three levels as shown in Table 5. The other parameters are fixed. The maximum repeat Best is 100,000 cycles. The maximum Iteration is 1,000,000 cycles and the answer time is 3,600 seconds.

**Table 5** Parameter and level of parameter of the experimental

| No. | Parameter | level | | |
|---|---|---|---|---|
| 1 | Tabu Size | 50 | 200 | 350 |
| 2 | Candidate List Size | 100 | 300 | 500 |

**Table 6.** Result of 27 methods of experimental

| ↓ | C1 StdOrder | C2 RunOrder | C3 PtType | C4 Blocks | C5 Tabu Size | C6 Candidate List Size | C7 Total Cost |
|---|---|---|---|---|---|---|---|
| 1 | 21 | 1 | 1 | 1 | 50 | 500 | 662790 |
| 2 | 15 | 2 | 1 | 1 | 200 | 500 | 662569 |
| 3 | 22 | 3 | 1 | 1 | 200 | 100 | 664055 |
| 4 | 16 | 4 | 1 | 1 | 350 | 100 | 664993 |
| 5 | 6 | 5 | 1 | 1 | 200 | 500 | 662420 |
| 6 | 8 | 6 | 1 | 1 | 350 | 300 | 662985 |
| 7 | 12 | 7 | 1 | 1 | 50 | 500 | 662709 |
| 8 | 18 | 8 | 1 | 1 | 350 | 500 | 662811 |
| 9 | 20 | 9 | 1 | 1 | 50 | 300 | 662868 |
| 10 | 1 | 10 | 1 | 1 | 50 | 100 | 663856 |
| 11 | 27 | 11 | 1 | 1 | 350 | 500 | 664232 |
| 12 | 5 | 12 | 1 | 1 | 200 | 300 | 662802 |
| 13 | 2 | 13 | 1 | 1 | 50 | 300 | 663211 |
| 14 | 25 | 14 | 1 | 1 | 350 | 100 | 664158 |
| 15 | 11 | 15 | 1 | 1 | 50 | 300 | 664542 |
| 16 | 23 | 16 | 1 | 1 | 200 | 300 | 662680 |
| 17 | 7 | 17 | 1 | 1 | 350 | 100 | 664148 |
| 18 | 17 | 18 | 1 | 1 | 350 | 300 | 663202 |
| 19 | 3 | 19 | 1 | 1 | 50 | 500 | 663313 |
| 20 | 13 | 20 | 1 | 1 | 200 | 100 | 663756 |
| 21 | 26 | 21 | 1 | 1 | 350 | 300 | 663116 |
| 22 | 4 | 22 | 1 | 1 | 200 | 100 | 664223 |
| 23 | 10 | 23 | 1 | 1 | 50 | 100 | 664158 |
| 24 | 9 | 24 | 1 | 1 | 350 | 500 | 664327 |
| 25 | 19 | 25 | 1 | 1 | 50 | 100 | 663695 |
| 26 | 24 | 26 | 1 | 1 | 200 | 500 | 662830 |
| 27 | 14 | 27 | 1 | 1 | 200 | 300 | 663030 |

***Parameter analysis***

The optimal parameter analysis with the Minitab program is the size of the Tabu Size of 200. The Candidate List Size is 500, so the total cost is 662,600 with the total satisfaction of 0.92755. Shown in Figure 2.

**TEST RESULT**

The test results from 10 times of experimental and selected the best answer found that Songkhla is suitable for establish 6 biomass power plants, as shown in Table 7.

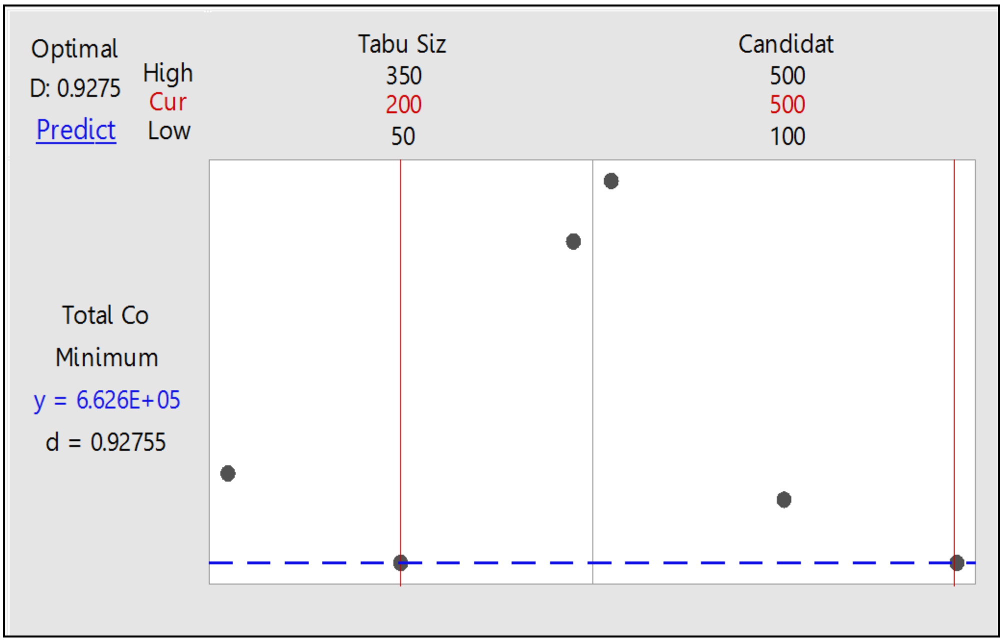


**Figure 2** Analysis factor of experimental

**Table 7.** Test result

| Location | Number of Supplier or Source | Raw material quantity (Ton/day) | Distance (Kilometer/day) | (Baht/day) | | | Total cost (Baht/day) |
|---|---|---|---|---|---|---|---|
| | | | | Depreciation of transmission line | Depreciation of Power plant | Cost of raw material transportation | |
| 2 | 19 | 300.634 | 663.4 | 70.37 | 107,808.22 | 2,653.6 | 110,532.2 |
| 27 | 6 | 302.078 | 635.7 | 4.02 | 107,808.22 | 2,542.8 | 110,355.0 |
| 32 | 8 | 303.805 | 448.2 | 1.01 | 107,808.22 | 1,792.8 | 109,620.0 |
| 41 | 25 | 301.526 | 882.5 | 6.03 | 107,808.22 | 3,530.0 | 111,344.3 |
| 69 | 17 | 305.587 | 630.6 | 26.14 | 107,808.22 | 2,522.4 | 110,356.8 |
| 85 | 12 | 323.266 | 620.5 | 16.08 | 107,808.22 | 2,482.0 | 110,306.3 |
| Total | 87 | 1,836.896 | 3,880.9 | 123.65 | 646,849.32 | 15,523.66 | 662,496.6 |

**Measure the effectiveness of the answer**

To test the performance of heuristic, Lingo 11 program had been used for measurement the efficiency of the answer. In order to confirm the performance of the heuristic and mathematical performance. There are 10 experimental dividing from the source, 8 sources, 10 sources, 12 sources, 14 sources, 16 sources, 18 sources, 20 sources, 40 sources and real problems at 87 sources. The answer, as shown in Table 8 and to test the significance of the average by t test and displays the results in Table 9.

**Table 8** Comparison of running program based on supplier

| Number of Supplier or Source (Unit) | Lingo 11 | | | Random Selection Neighborhood Methods ( Tabu Technique ) | | Variation Cost (Bath/day) | Variation Time (Bath/day) |
|---|---|---|---|---|---|---|---|
| | Status | Time (hrs.) | Total cost (Bath/day) | Program running time (hrs.) | Total Cost (Bath/day) | | |
| 6 | Global Optimal | 0:00:07 | 217,216 | 00:02:00 | 217,216 | 0.00 | 00:01:53 |
| 8 | Global Optimal | 0:01:46 | 217,228 | 00:02:00 | 217,228 | 0.00 | 00:00:14 |
| 10 | Global Optimal | 0:02:04 | 217,276 | 00:02:00 | 217,276 | 0.00 | 00:00:04 |
| 12 | Global Optimal | 10:03:10 | 217,472 | 00:02:00 | 217,472 | 0.00 | 10:00:50 |
| 14 | Feasible | 24:00:00 | 217,810 | 00:02:00 | 217,800 | 10.00 | 23:58:00 |
| 16 | Feasible | 24:00:00 | 218,351 | 00:02:00 | 217,682 | 669.00 | 23:58:00 |
| 18 | Feasible | 24:00:00 | 219,040 | 00:02:00 | 218,223 | 817.00 | 23:58:00 |
| 20 | Feasible | 24:00:00 | 220,071 | 00:02:00 | 218,035 | 2,036.00 | 23:58:00 |
| 40 | Unknown | 67:21:30 | - | 00:02:00 | 224,317 | - | - |
| 87 | Unknown | 83:41:18 | - | 01:40:15 | 662,317 | - | - |

**Table 9** Testing the significance of the mean by testing t

| Method | Average | SD. | t | P-Value |
|---|---|---|---|---|
| Lingo | 218,058 | 1,036 | 1.13 | 0.277 |
| Tabu | 217,617 | 383 | | |

The results of the performance measurement were statistically significant at the level of 0.05. It can be concluded that the tabu search heuristic search method can be used to find solutions to problems effectively.

## CONCLUSIONS

This research aims to study the problem solving of location selection and raw material transportation routing for biomass power plant. This research is to study and develop solution of problem solving of location selection and raw material transportation routing for biomass power plant. To determine the suitable number of power plants with the spatial biomass in term of location and to find the minimize total cost. The result from testing found that Songkhla Province, Thailand is suitable to set up the biomass power plant. The six suitable locations comprise of (1) The second location in Tunglan sub-district, Klonghoikhong district (2) The twenty-seventh location in Sadao sub district, Sadao district (3) The thirty second location in Thapo sub district, Sadao district (4) The forty first location in Chalung sub district, Hatyai district (5) The sixty ninth location in Natawee sub district, Natawee district (6) The eighty fifth location in Khaodaeng sub district, Sabayoy district. The figure of transportation cost is 15,233.66 baht per day while the total operation cost is 662,496.6 baht per day.

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