Transportation Cost Reduction by Applying a Hybrid Ant Colony System Algorithm, a Case Study: V-Drink Factory, Kalasin, Thailand

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Abstract

Logistics management is an essential component to increase business competitiveness for SMEs in the era of Thailand 4.0. With the aid of technology and innovation development, logistics management must provide both proper customer support and cost reduction in the delivery of goods. This research studied the routing of goods delivery for a drinking water factory seeking the shortest route with an objective of reducing the delivery cost. We proposed a hybrid goods delivery routing algorithm. The algorithm produced from the original routing was also tested and compared with the proposed hybrid algorithm. The comparison results showed that the Ant Colony System (ACS) routing gave the best solution when compared to the Genetic Algorithm (GA), the Simulated Annealing (SA) and the Tabu Search (TS). We then combined the ACS with an Iterated Local Search (ILS) and a TS. The results, when compared with the original route, indicated that the proposed Hybrid Ant Colony System Algorithm routing can reduce the distance and fuel cost by 2.24% per week, working out to approximately 887.52 baht per year. Meanwhile, it can reduce delivery time for 1 cycle from 7 days to 5 days, which can reduce labor costs by up to 46,080 baht per year. The proposed hybrid algorithm is a technological implementation that can be considered to reduce the manufacturing and transportation costs of for this drink factory business.

Keywords: Ant Colony System / Tabu Search / Iterated Local Search

Introduction

The current economic development model for Thailand, called “Thailand 4.0”, emphasizes technologies and innovations increasing the value of goods and services, has determined that logistics management provides important approaches for increasing the competitiveness of business. The applied technologies and innovations including production cost management, productivity, customer need responsiveness, and improvements in trade and business, lead to increased efficiency with lower costs for production and transportation.

The drinking water business is a rapidly growing business, but, it is highly competitive. The business involves a large number of local customers and yet tends to be a small or cottage industry, thus, the delivery routes for goods tend to be based on a combination of the experiences of the drivers and the decisions made by the business, without a clear plan. Late deliveries for customers took place very often because of the nonsystematic delivery routes and the overly long delivery time. These problems led to high delivery costs. Therefore, technology and innovation integration are necessary to manage drinking water logistics in order to respond to customer needs and to reduce the costs of goods delivery.

Transportation route arrangement is an approach that reduces business costs. There are many research studies on this topic, for example, Siriolarn (2014) used a development program to determine optimal vehicle routing which reduced transportation costs by 18.15% and Wonginta et al. (2018) studied transportation cost reduction and vehicle routing efficiency improvement, and found that by applying the principles of Milk Run routing they were able to reduce transportation costs by 16.5% per run.

ACS is a metaheuristic solution preferred to solve routing problems. The solution involves imitating the foraging behavior of ants, the depositing of pheromones and returning to the colony (Dorigo et al., 1996). Being similar to travelling salesman problem (TSP) and vehicle routing problem (VRP) made ACS preferred amongst researchers, as shown in much research. The ACS has been tested with businesses that require route planning, such as the goods delivery business (Srisuwandee and Pitakaso, 2012) and tourism business (Aumdee et al., 2016) and include research that studies transportation route arrangements with the ACS method under a variety of restrictions (Chen et al., 2007; Sandhya and Katiyar, 2013).

The first section of this research compares the metaheuristics including ACS, GA, SA and TS. The objective is to determine which algorithm provides the shortest route for the research problem. The results revealed that ACS is the best solution for our problem because it conforms to the ACS and GA comparison study conducted by Zhang and Yi (2016). Therefore, we choose the ACS.

We found that by routing with the ACS gave an improved solution over the ILS. The improvement in solution with the ACS was repeatable and gave the same solution with randomized numbers in the algorithm and using probability calculations to find the solution outcome with each iteration. The reasoning corresponds well with the ACS routing study discussed in the first section. By iteratively applying the solution we kept reaching the same answer. Therefore, the second section of attempts to prevent duplicated answers, to increase the possibility of finding a better solution.

TS is a metaheuristic that uses computer memory to collect previous answers and ignore them in next calculation. It extends the range of results and increases the chances for a better result. TS and ACS have been used in combination in recent studies to solve other problems. For example, Ayob and Jaradat (2009) studied Course Timetabling Problems by combining the TS and ACS with ILS, and exposed a better result. For VRP problems, TS can also be used in hybrid with other metaheuristic methods as in Thangiah's research (1999) in which a hybrid of SA, GA, and TS were used to find better solutions.

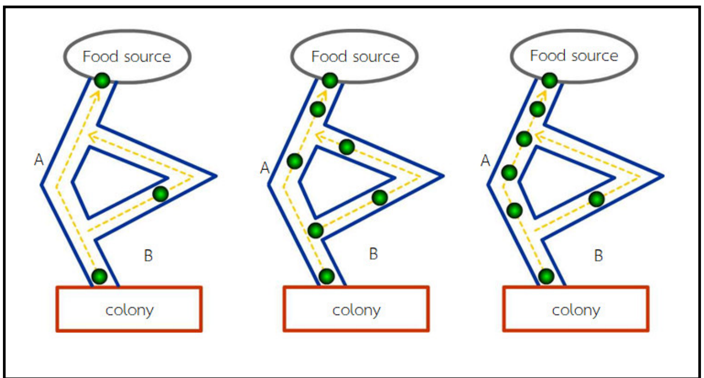
The current study looked at goods delivery routing for the V-Drink factory, Kalasin as a case study. The objective was to use a hybrid ACS to determine the shortest delivery route to customers to reduce fuel costs and delivery time. The reduced time would result in a reduction of labor costs both in transportation and manufacture. Therefore, costs for the factory would be reduced while satisfying customer needs leading to customers more pleased with the service.

Objective

The primary objective is to present a hybrid ACS which determined the shortest route to all customers to reduce transportation costs by reducing distance and delivery time.

Related Literature

The ACS (Pitakaso, 2011) is a concept developed from studying and imitating the foraging behavior of ants (Figure 1A). Each ant releases pheromones on the path it takes (Figure 1B). Naturally, ants chooses the path with a denser pheromone path. If the route taken is shorter than others, the pheromone path will be denser attracting other ants to follow (Figure 1C).



A B C

Figure 1. Ant foraging trails.

For that reason, the foraging behavior of ants, the pheromone deposition, and the return to the colony resemble the routing problem. The current research iteratively applied ACS to adjust pheromones and related parameters including ant population, pheromone, and attractiveness or ω(i,j). There are also two constant values, α is a control factor for pheromones and β is a factor control for the connecting path distance. The path for attraction finding follows this equation (1).

$$\omega(i,j) = \tau_{i,j}^{\alpha} x \pi_{i,j}^{\beta} \tag{1}$$

Based on equation (1), ω(i,j) is attractiveness for travel from the colony i to j and $\tau_{i,j}^{\alpha}$ is the pheromone for the trip from colony i to j controlled (powered) by α, and $\pi_{i,j}^{\beta}$ is the inverse of the distance between the two colonies controlled by β whereas $\pi = \frac{1}{d_{i,j}}$ where $d_{i,j}$ is the distance between colony i and colony j.

For new iterations, the pheromone is always updated with the best ant path from the specific iteration taking place before the new iteration begins. This research chose ACS as a means to adjust the pheromone. The pheromone update of ACS adjusted the pheromone following the equation (2).

$$\tau_{i,j}^{n} = \begin{cases} (1-\rho)(\tau_{i,j}^{n-1}), & \text{If i,j is not in the path where ant was chosen to travel update.} \\ (1-\rho)(\tau_{i,j}^{n-1}) + \pi^{l}, & \text{If i,j is in the path where ant was chosen to travel update.} \end{cases} \tag{2}$$

What makes ACS different from other pheromone updates is $p_{i,j}$ the calculation, which can be done in the equation (3).

$$p_{i,j} = \frac{\tau_{i,j}^{\alpha} \times \pi_{i,j}^{\beta}}{\sum_{j=1}^{J \in S} (\tau_{i,j}^{\alpha} \times \pi_{i,j}^{\beta})} = \frac{\omega(i,j)}{\sum_{j=1}^{J \in S} \omega(i,j)} \tag{3}$$

GA is a metaheuristic for simulating genetic inheritance to guide in the selection of a solution and evolve from generation to generation towards the best solution. The main elements of the GA include the chromosome design representing a solution, the initial population generation, finding an equation representing the individual, and an operation to create an inheritance from one generation of the population to a new generation.

SA is an improvement over the Basic Local Search (BLS). The basic concept of BLS is to conduct a best solution search in a fixed and possible answer area. In contrast, the SA concept includes the current solution, which is to be accepted as a new solution, which may not be the best solution. To consider whether the worse solution should be accepted, a probability is used, a function to Z(S), Z(S') and temperature. Temperature decreases corresponding to a number of the search iteration cycle. If Z(S) is accepted, it is set as an initial solution to search for a locally optimal solution. If the temperature or search iteration cycle reaches a defined number the iteration stops.

The TS algorithm is an algorithm with concept roots from the BLS like the ILS. The TS takes experiences from a number of previous iteration cycles (search history) by implementing the computer's RAM to prohibit some or all of the best solutions from the last cycle from being a part of the new solution in the current cycle. Thus the TS prevents encountering duplicated answers. The current research study combines elements of the ACS, ILS, and TS to find the shortest delivery route to reduce the transportation cost. The hybrid ACS algorithm can be written in pseudo-code as follows.

```
Initialize related value
  While iteration cycles do not reach defined number, do
     While ant number does not reach defined number
       Initialize S and set S* = S, Z(S*) Z(S) and Tabu List: TS = {S}
       While cycle = n
           Find solution S' which has the best solution in N(S) or Z(S') = min(Z(N(S))
           and N(S) ∈ TL); (Find N(S) by switching 2nd position with 3rd position
           up until colony at last position is switched and then stop)
           If Z(S') <= Z(S*), set S* = S' and TL = {S}
           Do S* perturbation by randomizing two positions and then switch position
       Stop iteration
     End generation of solution from each ant
     Update pheromone and parameters
  Stop iteration
```

Research Methodology

This research presents routing using a hybrid ACS to reduce transportation costs. Before routing by such an algorithm, we compared several routes with the original algorithm to determine the shortest routing algorithm for this problem. Then, we took the best algorithm and combined it with the ILS and the TS. The resultant solution is compared to the original distance to calculate reduced transportation costs.

1. Data collection and preparation

Goods delivery routes for this research covered an area of 37 villages located at Huai-Mek and Nong Kungsri, Kalasin. We surveyed all the delivery routes in one week recording customer location and the amount of goods demand for each customer. Then, areas of delivery were divided by area proximity. Customers in the same village were divided into the same area. Goods demands for customers was also taken into consideration because the demand must correspond to the load capacity for each run.

The total area was divided into 27 areas or 27 paths (column Area in Table 2) for delivery. The spot covering delivery route to each customer residence was determined for each area. Customers within the same district were put in the same spot. A spot was combined with other if there was a very small amount of customers in the district. Then, the distance from the factory to all spots of each area were measured and put in a matrix tabled as shown in Table 1.

Table 1 : Data matrix of distance from i to j, area: Kum Hai village (Kilometers).

i/j	1	2	3	4	5	6	7
1	0	5.20	5.40	5.30	5.40	5.70	5.70
2	5.20	0	0.15	0.35	0.50	0.75	0.75
3	5.40	0.15	0	0.18	0.35	0.65	0.60
4	5.30	0.35	0.18	0	0.19	0.45	0.40
5	5.40	0.5	0.35	0.19	0	0.25	0.21
6	5.70	0.75	0.65	0.45	0.25	0	0.25
7	5.70	0.75	0.60	0.4	0.21	0.25	0

2. Test for parameter optimization

The next procedure was to use these factors to calculate the shortest route and all routing algorithms were compared including the ACS, GA, SA, and TS. As related parameters must be set, we performed a parameter test that gave the best solution in each algorithm for this problem. Results were as follows.

ACS: Iteration = 25 cycles, Ant population = 10, Initial pheromone = 1, Pheromone evaporation rate = 0.03, and α , β = 3

GA: Iteration = 100 cycles, Mutation probability = 0.85, Crossover probability = 0.1, Chromosome number = Spot number for each area

SA: Iteration = 100 cycles, Initial temperature = 100°C, Iteration cycles until temperature change = 2, Temperature decrease at each change = 5

TS: Iteration = 1,000 cycles, Tabu Tenure = 2

3. Calculation and comparison of routing

This procedure was a comparison of each algorithm. Each algorithm was tested 3 times, and the one providing the shortest route was selected. In the case where there was more than 1 shortest route, the calculation time was then taken into consideration and the route using less time was selected. After 3 times of calculation for all algorithms, the one that provided the shortest route was selected. Then, this solution was compared to the original route, and other algorithms. The result is shown in Table 2.

Table 2 : Routing comparison by algorithms.

Area	Original Distance (km.)	ACS		GA		SA		TS	
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)
Huai-Mek (1)	6.87	**1-2-3-5-6-4-1**	**6.59**	1-2-3-4-6-5-1	6.77	1-3-4-2-5-6-1	7.23	1-2-4-3-5-6-1	6.78
Huai-Mek (2)	5.54	**1-2-3-4-5-6-7-1**	**5.34**	1-3-4-5-6-7-2-1	5.36	1-3-4-5-6-2-7-1	5.73	1-2-7-6-5-4-3-1	5.36
Huai-Mek (3)	6.56	**1-3-7-5-4-6-2-1**	**6.49**	1-2-4-3-7-5-6-1	6.56	1-2-6-4-7-5-3-1	6.84	**1-2-6-4-5-7-3-1**	**6.49**
Huai-Mek (4)	7.15	**1-5-2-3-4-6-1**	**7.15**	1-2-3-4-5-6-1	7.16	1-3-4-2-5-6-1	7.44	1-2-3-4-5-6-1	7.16
Pan Suwan (1)	3.83	**1-2-4-3-6-5-1**	**3.78**	**1-2-4-3-6-5-1**	**3.78**	1-5-6-4-3-2-1	3.87	1-5-4-3-6-2-1	3.80
Pan Suwan (2)	4.20	**1-5-2-4-3-1**	**3.95**	1-2-4-3-5-1	4.15	1-2-4-5-3--1	4.50	**1-5-2-4-3-1**	**3.95**
Hatanwa	5.0	**1-2-6-5-3-4-1**	**5.0**	**1-4-3-5-6-2-1**	**5.0**	1-5-4-6-3-2-1	8.4	**1-5-4-3-6-2-1**	**5.0**
Pitak	7.20	1-2-4-3-5-6-	6.68	**1-4-6-5-3-2-**	**6.59**	1-3-2-4-6-5-	6.99	1-2-4-3-5-6-	6.68

Area	Original Distance (km.)	ACS		GA		SA		TS	
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)
		1		**1**		1		1	
Chan Songla	6.10	**1-2-3-4-5-7-6-1**	**5.34**	1-3-5-4-6-7-2-1	5.52	1-3-2-4-5-7-6-1	5.88	1-2-4-3-5-6-7-1	5.55
Nor Kam	9.68	**1-4-3-2-5-1**	**8.99**	1-5-2-4-3-1	9.18	1-3-2-4-5-1	9.49	1-2-3-5-4-1	9.03
Tat	10.64	1-2-3-4-5-1	10.60	**1-4-3-2-5-1**	**10.44**	1-5-4-2-3-1	11.02	1-3-2-5-4-1	10.64
Chaisri	7.55	**1-2-4-5-6-3-1**	**7.25**	**1-3-6-5-4-2-1**	**7.25**	1-5-6-3-4-2-1	7.75	**1-2-4-5-6-3-1**	**7.25**
Huiyang	7.66	**1-2-5-4-6-7-3-1**	**7.47**	1-5-6-4-2-3-7-1	7.63	1-7-5-6-2-3-4-1	7.58	1-5-3-4-2-7-6-1	7.56
Kood Don	22.70	**1-3-4-5-6-2-1**	**20.25**	**1-2-6-5-4-3-1**	**20.25**	1-3-5-4-6-2-1	20.65	**1-2-6-5-4-3-1**	**20.25**
Non Sawan (1)	31.58	**1-5-4-3-2-1**	**31.58**	**1-2-3-4-5-1**	**31.58**	1-4-3-2-5-1	31.73	**1-2-3-4-5-1**	**31.58**
Non Sawan (2)	31.71	1-2-6-5-3-4-1	31.77	1-4-5-6-2-3-1	31.81	1-4-2-3-5-6-1	32.11	**1-4-2-6-5-3-1**	**31.71**
Non Keekuang	32.56	1-4-3-6-5-2-1	32.42	**1-3-6-5-4-2-1**	**32.41**	1-4-3-5-6-2-1	32.57	1-2-4-3-5-6-1	32.55
Kam Hai	12.28	**1-5-6-7-4-3-2-1**	**11.83**	1-5-7-6-4-3-2-1	11.84	1-4-6-5-7-2-3-1	12.51	1-2-3-4-5-6-7-1	11.92
N. Rew Nung	27.58	**1-2-3-5-6-4-1**	**27.43**	**1-2-3-5-6-4-1**	**27.43**	1-3-6-2-5-4-1	29.23	1-4-5-3-2-6-1	27.58

Area	Original Distance (km.)	ACS		GA		SA		TS	
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)
N. Hor Tri	30.27	**1-2-3-4-5-6-1**	**29.74**	1-6-5-3-4-2-1	30.15	1-3-5-4-6-2-1	30.14	1-4-3-2-6-5-1	29.99
N. Kung Puak	30.95	**1-4-3-2-5-6-1**	**30.85**	**1-4-3-2-5-6-1**	**30.85**	1-6-5-4-3-2-1	33.00	1-6-3-2-4-5-1	31.65
N. Kungsri (1)	24.65	1-2-3-6-4-5-1	24.15	**1-3-5-4-6-2-1**	**23.85**	1-2-3-4-5-6-1	24.20	1-2-5-4-6-3-1	24.15
N. Kungsri (2)	25.81	1-2-4-6-5-3-7-1	26.21	**1-7-4-6-5-3-2-1**	**25.96**	1-5-4-6-3-2-7-1	26.39	1-2-3-4-6-7-5-1	26.56
N. Kungsri (3)	23.95	**1-2-3-4-6-5-1**	**23.95**	**1-2-3-4-5-6-1**	**23.95**	1-4-5-3-2-6-1	24.95	**1-2-3-4-6-5-1**	**23.95**
Non Sila (1)	20.77	**1-3-5-4-6-2-1**	**20.72**	1-6-5-2-3-4-1	20.77	1-5-6-4-3-2-1	20.82	1-5-6-4-3-2-1	20.82
Non Sila (2)	20.48	**1-3-2-4-5-1**	**20.22**	1-2-4-3-5-1	20.29	1-5-2-3-4-1	20.57	**1-3-2-4-5-1**	**20.22**
Sa-ard Nadee	22.40	**1-2-5-7-6-4-3-1**	**21.41**	1-3-2-5-7-6-4-1	21.51	1-5-4-6-7-2-3-1	21.95	1-3-4-2-6-7-5-1	21.70

Based on Table 2, it was found that the ACS routing resulted in the best solution for 21 out of 27 villages. The second best was the GA which result in the best solution for 13 villages. This was followed by the TS which resulted in the best solution for 9 villages. The SA did not result in a better solution than the others. Next, the ACS, the algorithm giving the best result, was improved by using the ILS which used the SWAP method and perturbation to increase the chance for a better result. To prevent the duplication of answers the TS, an algorithm preventing repeated solutions, was used; it was also a hybrid with the ACS and ILS.

Results and Discussions

We took the Hybrid ACS, a combination of the ACS, ILS, and TS algorithm, to program with Visual Studio 2017 and to test the algorithm with an Intel(R) Core(TM) i5-2410M CPU @ 2.30 GHz Ram 6 GB computer. The ACS, ACS+ILS, and ACS+ILS+TS routing were compared altogether by the same processing to prove that the proposed Hybrid Ant Colony System results provided a better routing than the ACS and the commonly-used improved ACS algorithms. The comparison results are shown in Table 3.

Table 3 : The comparison results of the proposed routing algorithm vs. the competitors.

Area	Original Distance (km.)	ACS		ACS+ILS		ACS+ILS+TS		Reduced Distance (%)
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	
Huai-Mek (1)	6.87	1-4-3-2-5-6-1	7.22	1-2-3-4-6-5-1	6.77	1-2-3-5-6-4-1	6.59	4.08
Huai-Mek (2)	5.54	1-3-4-5-7-6-2-1	5.47	1-3-4-5-6-7-2-1	5.36	1-2-3-4-5-6-7-1	5.34	3.61
Huai-Mek (3)	6.56	1-6-2-4-5-7-3-1	6.72	1-2-6-4-5-7-3-1	6.49	1-2-6-4-5-7-3-1	6.49	1.07
Huai-Mek (4)	7.15	1-2-4-3-5-6-1	7.50	1-3-2-5-4-6-1	7.25	1-5-2-3-4-6-1	7.15	0
Pan Suwan (1)	3.83	1-5-2-4-3-6-1	3.81	1-2-4-3-6-5-1	3.81	1-3-4-2-6-5-1	3.78	1.31
Pan Suwan (2)	4.20	1-3-4-2-5-1	4.20	1-5-2-3-4-1	4.15	1-5-4-3-2-1	3.95	5.95
Hatanwa	5.0	1-2-6-5-3-4-1	5.00	1-2-6-5-3-4-1	5.00	1-6-5-4-3-2-1	5.00	0
Pitak	7.20	1-2-4-3-5-6-1	6.68	1-3-4-6-5-2-1	6.63	1-2-4-6-5-3-1	6.50	9.72
Chan Songla	6.10	1-2-3-4-5-7-6-1	5.34	1-3-4-5-6-7-2-1	5.26	1-3-4-5-6-7-2-1	5.26	13.77
Nor Kam	9.68	1-2-4-3-5-1	9.03	1-4-3-5-2-1	8.99	1-2-3-5-4-1	8.99	7.13
Tat	10.64	1-2-3-4-5-1	10.64	1-4-3-5-2-1	10.60	1-2-3-5-4-1	10.44	1.88
Chaisri	7.55	1-2-4-5-6-3-1	7.25	1-2-4-5-6-3-1	7.25	1-3-6-5-4-2-1	7.25	3.97

Area	Original Distance (km.)	ACS		ACS+ILS		ACS+ILS+TS		Reduced Distance (%)
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	
Huiyang	7.66	1-6-7-2-5-4-3-1	7.62	1-2-7-6-5-4-3-1	7.39	1-3-4-5-6-7-2-1	7.39	3.52
Kood Don	22.70	1-3-5-6-4-2-1	20.30	1-2-6-5-4-3-1	20.25	1-3-4-5-6-2-1	20.25	10.79
Non Sawan (1)	31.58	1-4-3-2-5-1	31.73	1-5-4-3-2-1	31.58	1-2-3-4-5-1	31.58	0
Non Sawan (2)	31.71	1-4-3-2-5-6-1	32.17	1-3-2-6-5-4-1	31.81	1-3-5-6-2-4-1	31.71	0
Non Keekuang	32.56	1-4-2-3-5-6-1	32.76	1-2-4-5-6-3-1	32.41	1-4-5-6-3-2-1	32.38	0.55
Kam Hai	12.28	1-4-3-2-6-7-5-1	12.24	1-2-3-4-6-7-5-1	11.84	1-2-3-4-7-6-5-1	11.83	3.66
N. Rew Nung	27.58	1-2-3-5-6-4-1	27.58	1-3-5-6-4-2-1	27.53	1-2-5-6-4-3-1	27.43	0.54
N. Hor Tri	30.27	1-3-4-6-5-2-1	29.77	1-5-6-4-3-2-1	29.74	1-3-6-4-5-2-1	29.74	1.75
N. Kung Puak	30.95	1-4-2-3-5-6-1	31.35	1-2-4-3-5-6-1	30.85	1-6-5-4-3-2-1	30.85	0.32
N. Kungsri (1)	24.65	1-3-2-5-4-6-1	24.25	1-3-6-4-5-2-1	24.15	1-2-3-5-4-6-1	23.85	3.25
N. Kungsri (2)	25.81	1-4-3-6-7-5-2-1	26.83	1-2-3-5-4-6-7-1	25.81	1-2-3-4-5-6-7-1	25.75	0.23
N. Kungsri (3)	23.95	1-3-2-5-4-6-1	24.90	1-2-3-4-5-6-1	23.95	1-2-3-4-6-5-1	23.95	0
Non Sila (1)	20.77	1-2-6-3-5-4-1	20.74	1-2-6-3-5-4-1	20.74	1-2-4-5-3-6-1	20.72	0.24
Non Sila (2)	20.48	1-2-4-3-5-1	20.29	1-2-4-3-5-1	20.29	1-4-2-3-5-1	20.22	1.27
Sa-ard Nadee	22.40	1-3-2-5-7-6-4-1	21.51	1-2-5-7-6-4-3-1	21.41	1-3-4-5-7-6-2-1	21.30	4.91
Total Distance	445.67	442.90		437.31		435.69		2.24

Area	Original Distance (km.)	ACS		ACS+ILS		ACS+ILS+TS		Reduced Distance (%)
		Route	Distance (km.)	Route	Distance (km.)	Route	Distance (km.)	
Fuel Cost (Baht)	825.68	820.55		810.19		807.19		

Based on Table 3, the ACS+ILS routing resulted in a better solution than the ACS routing. It gave a better result for 22 out of 27 villages. Moreover, ACS+ILS+TS routing resulted in a better solution than the ACS routing for 25 out of 27 villages. When comparing transportation cost reduction to delivery route during a week, the original total distance recorded from the survey was 445.67 km. with a diesel fuel cost of 825.68 baht (Data as of November 29, 2018, 27.79 baht per liters, fuel consumption rate is 15 km./liter). It was found that ACS routing has a total distance of 442.90 km., that is 2.77 km. less than the original distance. The fuel cost is 820.55 baht, reduced by 5.13 baht. Also, the ACS+ILS routing has a total distance of 437.31 km., that is 8.36 km. less than the original distance. The fuel cost is 810.19 baht, reduced by 15.49 baht. Lastly, the ACS+ILS+TS has a total distance of 435.69 km., 9.98 km. less than the original distance. The fuel cost is 807.19 baht, reduced by 18.49 baht. Thus the hybrid ACS helped reduce both the distance and fuel costs by 2.24% per run. These results are shown in Figure 2.

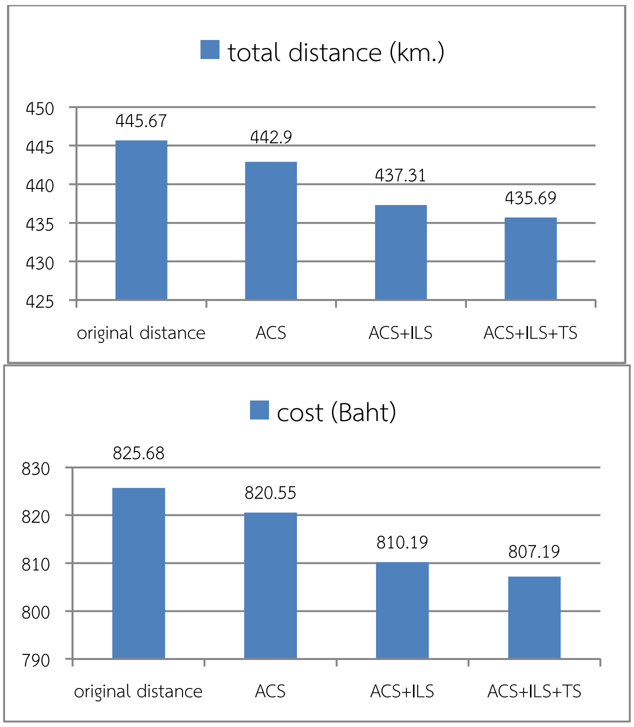


Figure 2. Distance and fuel cost comparison after Hybrid Ant Colony System routing.

When calculating fuel costs throughout the year, they can be reduced by 887.52 baht per year. In addition, the new route provides a shorter distance. When the delivery plans were rescheduled, the delivery time decreased from 7 days to 5 days. The labor cost also decreased from 276,480 baht per year to 230,400 baht per year, i.e., saving up to 46,080 baht per year.

Conclusions and Suggestions

The primary objective of this research is to reduce transportation costs by reducing distance and delivery time, by studying and developing a routing algorithm for finding the shortest distance. This research used hybrid algorithms after the routing from the original algorithms were tested. The ACS was the algorithm that gave the best solution when compared to GA, SA, and TS. With the ACS as a hybrid with the ILS and TS, the repetition of the same solution was avoided increasing the possibility for more results which led to obtained the best solution. This reduced distance helps save the money spent which favorably reduces the drink factory's cost. However, many different parameters were applied to compare the algorithms in the first section. We performed the tests to obtain the optimal settings for this research. The parameters may change when the algorithm is performed on other problems. Therefore, the optimal parameters should be tested for various problems, to find the best solution. In addition, in some transportations, there are limitations that affect the routing. For example, limited-time delivery routing, unknown or uncertain customer needs delivery, or delivery with loading limitations. Which researchers have to take these limitations to consideration as well.

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