JAREE-Journal on Advanced Research in Electrical Engineering
Volume 2, Number 1, April 2018

Optimization of Vehicle Routing Problem with Tight Time Windows, Short Travel Time and Re-used Vehicles (VRPTSR) for Aircraft Refueling in Airport Using Ant Colony Optimization Algorithm

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***Abstract*— Scheduling in aircraft refueling has an important role in aviation. Scheduling of aircraft refueling is called Airport Ground Service Scheduling (AGSS) that can be formulated as *Vehicle Routing Problem with Tight time windows, Short travel time and Re-used Vehicles* (VRPTSR) This research is focusing in scheduling design for aircraft refueling with *refueller* truck in Juanda Airport, Surabaya, so minimum amount of truck will be used using *Ant Colony optimization*. The result shows that *Ant Colony optimization* could do scheduling in refueling well so minimum amount of truck will be used.**

Keywords*— *Scheduling, Vehicle Routing Problem with Tight time windows, Short travel time and Re-used Vehicles, Ant Colony Optimization

I. INTRODUCTION

Aircraft handling in ground (ground service) happen when the aircraft landed until ready to be flown. Ground service consist of unloading and loading of passengers, aircraft sanitation, and aircraft necessities. The necessities consist of aircraft pullers, fire fighters, and aircraft refueling.

Aircraft refueling has an important role in aviation. Institution which facilitate and responsible in refueling is Depot Pengisian Pesawat Udara (DPPU) Juanda, Pertamina. To support the service of refueling operation, along with the progress and the density of aviation world, then in the airport, especially medium and large airport, there is facilities to refuel an aircraft. The facilities which refuel an aircraft composed of 2(two) types of refueling, using the pipeline below *apron* and using *refueller* truck. This research is focusing on the aircraft refueling using *refueller* truck.

A Multi-Agent Algorithm DSAFO for AGSS was presented by Fan Xue and Wei Fan [2], which discussed vehicle scheduling without need to take vehicle capacity into account, such as baggage tractor scheduling, etc. DSAFO divided the search domain into several partitions, with an agent searching in each partition, which could get a locally optimum. Meanwhile, a global coordination mechanism was used to find the global optimum. XING et al. [7] studied the second kind of AGSS. In this paper, the first kind of AGSS is studied, formulated as VRP with tight time windows, short travel time, capacity constraint and reused vehicles (VRPTSR). Zhang et al. [5] presented an ACO to solve Vehicle Routing Problem with Time Windows and Reused Vehicles□VRPTWRV□in logistical industry, which is different from the features in airport ground services.

In this research, *Ant Colony optimization* algorithm is used to solve *Vehicle Routing Problem with Tight time windows, Short travel time and Re-used Vehicles* (VRPTSR) in aircraft refueling in airport to minimize the total of truck used.

II. PROBLEM STATEMENT

A. *Problem Description*

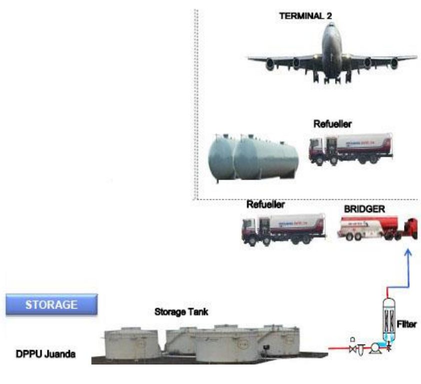

Fig. 1. Fuel distribution system

In this system, aviaton fuel from storage tank will be distributed to consumers in terminal 1 and 2 using a few vehicles and pipeline (*hydrant pit*). To distribute to terminal 1 that already has *hydrant pit* and then go into *hydrant dispenser* to refuel the aircraft, besides in terminal 1 there is also *refueller* whose job is to fuel the aircraft directly. While in terminal 2 doesn't have a *hydrant pit*, instead it has its own storehouse that will be filled by *bridger*. The storehouse itself will be used to fill the availability of the aviation fuel using *refueller* so the *refueller* will fuel the aircraft directly.

This research fixed on the discussion of *refueller* truck in terminal 2. The distribution processes in terminal 2 is as follows:

1. The distribution process in terminal 2 there is only two types of vehicle, bridger truck and refueller truck.
2. Bridger truck take the aviation fuel and distribute them to the storehouse located in terminal 2.
3. Storehouse in terminal 2 is used to fill the refueller truck with aviation fuel and become a parking spot for refueller truck.
4. After the demand of fuel on every refueller truck is fulfilled, then refueller truck is ready whenever the aircraft need to be refueled directly.

B. *Mathematical Model*

1) Decision Variable

$$y_k = \begin{cases} 1, \text{truk k yang diberangkatkan untuk digunakan} \\ 0, \text{jika tidak ada} \end{cases}$$

$$x_{ik} = \begin{cases} 1, \text{truk k yang siap ditugaskan untuk penerbangan i} \\ 0, \text{jika tidak ada} \end{cases}$$

2) Objective Function

Objective function of this research is to minimize the amount of truck needed in fuel distribution. Objective function could be defined as follows:

$$Min\ Z = \sum_{k=1}^{m} y_k \qquad (2.1)$$

3) Problem Limitation

$$\sum_{k}^{n} x_{ik} = 1, \quad \text{for } i=1,2,..,n \qquad (2.2)$$

$$\sum_{k}^{m} x_{ik} \leq G y_k \quad \text{for } k=1,2,...,m \qquad (2.3)$$

$$s_j + H(1-z_{ij}) \geq s_i + p_i + c_{ij} + H(x_{ik}+x_{jk} - 2), \qquad (2.4)$$

for $j \neq i$; $i, j = 1,2,...,n$; $k=1,2,....,m$

$$\sum_{i \in N} d_i \sum_{j \in N} x_{ij} \leq M_k \qquad (2.5)$$

$$x_{ik} + x_{jk} - 1 \leq z_{ij} + z_{ji} \leq 1, \text{ for } j \neq i;\ i, j = 1,2,...,n;\ k=1,2,....,m \qquad (2.6)$$

$$x_{ik}, z_{ij} \in \{0,1\}, \text{ for } i, j = 1,2,...,n;\ k=1,2,....,m \qquad (2.7)$$

$$s_i, \in \{a_i, b_i\}, \text{ for } i=1,2,...,n \qquad (2.8)$$

$$y_k \in \{0,1\}, \text{ for } k=1,2,...,m \qquad (2.9)$$

Objective function in equation (2.1) is to minimize the amount of truck used. Other than to complete objective function, this system also need to fulfill every possible limitation.

In limitation (2.2) explains that one aircraft only be served by one truck. Limitation (2.3) explains that every truck has a frequency in serving every day flight symbolized with G. Limitation (2.4) explains that flight j and flight i served by the same truck, then the service for flight j begins after flight i. Limitation (2.5) explains that the fuel demand of every aircraft cannot outsource the truck capacity. And in limitation (2.6) explains that in serving, trucks only served the order of flight i to j or vice versa.

III. Optimization Method

A. *Problem Description*

Ant Colony Optimization (ACO) is a method to solve optimization problem which imitates the behavior of ant colony when looking for food. ACO concept introduced first time by Ant System (AS) algorithm in 1992 by Marco Dorigo in his dissertation.

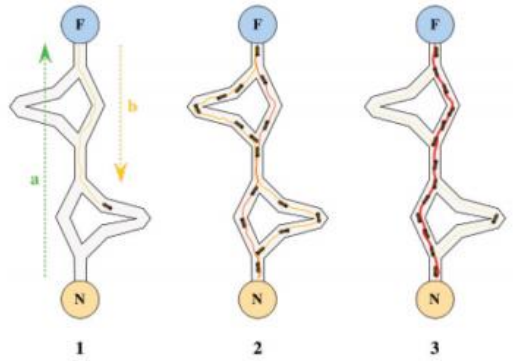

Fig. 2. Journey of Ants Looking for Food

Inspired by how ant colony look for the route to the source of food, this method imitates the communication system that leave a chemical substance pheromone in its route. Every ant starts the tour from a point which picked randomly (each ant has different starting point). Repeatedly, one at a time every point is visited by the ant to yield tour. The choice of the point in which need to be visited is based on a probability function, named state transition rule, by considering the visibility (invers of distance) of that point and the amount of pheromone in the segments which connected the points. Ant that found a food source, will leave pheromone in its route back to its colony. Other ants that smell the pheromone in a route, will tend to follow that route if the pheromone is heavy enough. The heavier the pheromone in a route, the higher the probability of other ants to follow that route. Pheromone will evaporate as time goes by. Short route will have a heavier rate of pheromone, because the time used to do a round trip (every time ant goes back to its colony, it always leaves pheromone) from the colony to the source of food is shorter, that results the evaporation rate of the pheromone in minimum.

Procedure of ACO algorithm (Dorigo, Gambardella) explained as follows [4]:

1) Determine the value of ACO parameters (the amount of ants M, iteration K, and many more) and initialize the amount of pheromone in every branch.
2) Determine the next node based on *state transition rule.*
3) Update the amount of pheromone in every branch that is passed by local pheromone update. Every ant will build a solution (route).

State Transition Rule that is used in the choice of the next node can be formulated as follows:

$$Sk(r,s) = \begin{cases} \arg\max_{U \in Jk(r)} \left\{ [\tau(r,u)].[\eta(r,u)]^{\beta} \right\}, & \text{if } q \le q_o \\ \dfrac{[\tau(r,s)].[\eta(r,s)]^{\beta}}{\sum_{u \in Jk(r)} [\tau(r,u)].[\eta(r,u)]^{\beta}}, & q \ge q_o \end{cases}$$

If $q \le q_o$, then it is exploitation, while if $q \ge q_o$, then it is exploration where

$\tau(r,u)$: the amount of pheromone on the side of node r to node u.
$\eta(r,u)$: (the length of node r to node u)$^{-1}$.
β : parameter of the comparison of the amount of relative pheromone to distance (the parameter determined before).
$J_k(r)$: set of node that is not visited yet by the k-th ant in *node* r.
$\tau(r,s)$: the amount of pheromone on the side of node r to node s.
$\eta(r,s)$: (the length of node r to node s)$^{-1}$.
q : random number.
q_0 : parameter that determine exploitation or exploration

Local Pheromone Update

Every time forming a tour, the ants will pass the branches and altered the amount of pheromone the equation:

$$\tau(r,s) \leftarrow (1-\rho).\,\tau(r,s) + \rho.\,\Delta\tau(r,s)$$

where

$\tau(r,s)$: the amount of pheromone on the side from node r to node s.
ρ : local parameter of missing pheromone.
$\Delta\tau(r,s)$: the amount of pheromone on the side of node r to s.

4) Sort the first solution until the M-th solution,keep the best solution as *BestIteration*.
5) Do a *local search*, in this case *insertion heuristic*, to *BestIteration*.
6) Do *global pheromone update* to *BestIteration*. After every ant pass every node the amount of pheromone will change based on *global updating rule* as follows:

$$\tau(r,s) \leftarrow (1-\alpha).\,\tau(r,s) + \alpha.\,\Delta\tau(r,s) \qquad (2.9)$$

$$\Delta\tau(r,s) = \begin{cases} \dfrac{1}{Lgb} & untuk (r,s) \in global-best-tour \\ 0 & lainnya \end{cases}$$

Where α is a pheromone global parameter that missing and Lgb is the length of the best tour yield by the ant colony.

7) In the first iteration, *BestIteration* = *BestSolution*.

In the second iteration to the K-th, If *BestIteration* > *BestSolution* then *BestIteration* = *BestSolution.*

IV. Method Testing and Result

In this ACO test, the method will be tested three times with the same amount of iteration which is 400. By changing the parameter in pheromone evaporation and the amounts of ants.

In the *pheromone* (ρ) evaporation testing, parameter ρ is made into another variation, which is 0,2; 0,5; 0,8 with the same amounts of ants and iteration which is 80 and 400.

In the amounts of ants (N) testing, parameter N is made into another variation, which is 40,60,80 with the same ρ and iteration which is 0,5 and 400.

This experiment took the data in 7 days.

TABLE I. Comparison of Parameter

	Amount of Truck							Total
	1	2	3	4	5	6	7	
Initial Condition	3	4	4	4	3	4	4	26
$\rho = 0,2$ **ant 80**	3	3	4	4	3	3	3	23
$\rho = 0,5$ **ant 80**	4	4	4	4	4	3	4	27
$\rho = 0,8$ **ant 80**	5	4	4	4	4	4	5	30
$\rho = 0,5$ **ant 40**	4	5	4	5	4	4	5	31
$\rho = 0,6$ **ant 60**	3	4	4	5	4	3	4	27

It is seen in table 1, in the initial condition, the total of truck used in 7 days is 26 trucks, as in the ant colony parameter testing, with parameter $\rho = 0,2$ ant 80 have the total of truck used in 7 days much fewer than other parameter, which is 23. So, by the result of the experiment, the parameter which produce optimum result, it is the parameter with value ρ=0,2, ant 80 and iteration 400.

The amount of truck used in refueling the aircraft by using ant colony algorithm could be seen in table 2.

By looking at table 2 we could see that the ant colony optimization algorithm produces fewer amount of truck than the initial condition before ant colony optimization is applied which is on date 2, 6, 7, 9, 12, 13, 14, 16, 21, 22, 24, 25, and 27.

TABLE II. COMPARISON OF ACO AND INITIAL CONDITION

Date	Amount of Risk	
	Initial Condition	ACO
1	3	3
2	4	3
3	4	4
4	4	4
5	3	3
6	4	3
7	4	3
8	3	3
9	4	3
10	4	4
11	3	3
12	5	4
13	6	4
14	4	3
15	3	3
16	5	3
17	3	3
18	4	4
19	3	3
20	4	4
21	5	4
22	4	3
23	3	3
24	4	3
25	4	3
26	3	3
27	5	4
28	4	4
29	3	3

The result of the refueling scheduling using ACO with ρ=0,2, ant=80 and iteration 400 could be seen in Table 3.

TABLE III. REFUELING SCHEDULING BASED ON ACO

Truck	Flight
RF 09	0-1(A6)-7(A4)-10(A6)-0
RF 09	0-11(A7)-12(A1)-0
RF 09	0-16(A4)-18(A1)-19(A2)-20(A6)-0
RF 09	0-22(A7)-26(A6)-27(A1)-28(A2)-31(A1)-0
RF 09	0-32(A6)-34(A1)-35(A2)-36(A3)-0
RF 09	0-38(A3)-41(A1)-42(A2)-43(A3)-44(A6)-45(A4)-46(A5)-0
RF 16	0-2(A1)-5(A3)-6(A6)-8(A5)-9(A1)-0
RF 16	0-13(A2)-14(A8)-15(A3)-0
RF 16	0-17(A5)-23(A8)-25(A2)-29(A6)-30(A3)-37(A6)-0
RF 16	0-39(A4)-0
RF 19	0-3(A2)-4(A7)-0
RF 19	0-24(A1)-0
RF 19	0-33(A2)-0
RF 19	0-40(A5)-0

V. CONCLUSION

Based on the result of experiment and analysis, it could be concluded as follows:

a. From parameter value analysis, the higher the value of ρ, then the truck used will increase.
b. When ρ is 0,8, then the truck used in 7 days are 30 trucks, and when ρ is 0,2, the truck used in 7 days are 23 trucks.
c. The implementation of *ant colony* algorithm, could decrease the amount of truck operated to refuel aircrafts in DPPU Juanda Terminal 2, Surabaya.

REFERENCES

[1] Du, Yuquan., Zhang, Qian., Chen Qiushuang."ACO-IH *An Improved Ant Colony Optimization Algorithm for Airport Ground Service Scheduling*", Nankai University, China, 2008.

[2] Fan Xue, Wei Fan "Multi-Agent Optimization Design for Multiresource Job Shop Scheduling Problem," in *Proc. 2007 International Conference on Intelligent Computing*, Qingdao, China, pp.1193-1204, Aug. 2007.

[3] Hilier, F. Lieberman, G "*Introduction to Operation* Research", McGraw-Hill, New York,2001.

[4] Santosa, Budi dan Paul Willy, "*Metoda Metaheuristik Konsep dan Implementasi*", Surabaya, Guna Widya, 2011.

[5] Tao Zhang, Shanshan Wang, Wenxin Tian, Yuejie Zhang, "ACOVRPTWRV: A New Algorithm for the Vehicle Routing Problems with Time Windows and Re-used Vehicles based on Ant Colony Optimization," in *Proc. of the Sixth International Conference on Intelligent Systems Design and Applications*, Jinan, China, pp. 390-395, Oct. 2006.

[6] Toth, P., Vigo, D."The Vehicle Routing Problem", SIAM Monograph on Discrete Mathematics and Applications. SIAM, Philadelphia, 2002.

[7] XING Jianmin, LIU Shaohua, FAN Wei, JI Lei, "Design of Airport Ground Service System Based on Multi-agent," *Journal of Civil Aviation University of China*, Vol.24, No.3, pp.24-27, June, 2006.