Using CVRP Model in Designing Decision Support System for Optimizing Distribution Route and Amounts of Utilized Vehicles

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***Abstract*—Capacitated Vehicle Routing Problem is one extensive kind of Vehicle Routing Problem that of great significance in management distribution and operation logistic. As the fundamental issue of CVRP is framing to minimize vehicle's operational cost, thus CVRP is an NP-hard problem which three bears of solutions are conventionally make use of heuristics, approximation, and exact methods. Through this paper, we show the design of Decision Support System based on SWA to deal with CVRP model which adequate for not only generating optimum route but also to amend amounts of utilized vehicles. As the result, we found that our DSS method is accomplishing to reduce both total distance and amounts of vehicles. total distance is compressing 37 percent, while amounts of vehicles used are abbreviating 15 percent.**

***Keywords*—capacitated vehicle routing problem; sweep algorithm; route and total vehicle optimization, distribution.**

I. Introduction

Capacitated Vehicle Routing Problem (CVRP) is one extensive kind of Vehicle Routing Problem that of great significance in management distribution and operation logistic[1]. As the fundamental issue of CVRP is framing to minimize vehicle's operational cost, thus CVRP is an NP-hard problem which three bears of solutions are conventionally make use of: heuristics, approximation and exact methods [2].

A variant that commonly used construction heuristics for the VRP is the sweep algorithm (SWA) which published in the beginning of 1970s. SWA works by clusters an accumulation of stops into a route based on the polar angle between the stops and the depot [3]. The SWA heuristic able to produce the optimum solution in CVRP model since it very useful in the context of practical [4][5]. However, extends research besides solving CVRP using SWA for optimizing route is rarely exist whereas Suthikarnnarunai [6] have been proposed that CVRP model using SWA afford to minimize the amounts of used vehicles.

Through this paper, we show the design of Decision Support System based on SWA to deal with CVRP model which adequate for not only generating optimum route but also to amend amounts of utilized vehicles. The proposed scenario of the process: first is user input the location of agents and total of demands, then the system would process those data using regulation that have been implemented into programming structure with SWA principal. The last, information about optimum route and amounts of used vehicles will be shown as output that concurs with decision maker's preferences. The designing DSS addressing a case of study PT. Pertamina Depo Malang, which this company is having a responsibility to distribute premium to the 15 gas stations in Malang City by exploiting 10 vehicles with the capacity is 24-kiloliters per vehicle.

This research paper is framed along these lines. Section 2 is distinguished the CVRP model. In Section 3, the blueprint of DSS Design is described in form of information system framework. In Section 4, the heuristics SWA is explained. The results of the experiment are reported in Section 5.

II. CVRP Model

The mathematical formulation of CVRP proposed by Fisher and Jaikumar [7] by the steps as follows. First setting up required notations.

Parameters

n	set of agents and depot
m	amount of vehicles
C	capacity of each vehicle
Di	need of agent i
d_{ij}^{k}	distance travel from agent i to agent j by vehicle k

Decision Variables

x_{ij}^{k} =	$\begin{cases} 1 & \text{if vehicle } k \text{ travels from agent } i \text{ to } j \\ 0 & \text{otherwhere} \end{cases}$
K	total of used vehicles

Single objective optimization problem of CVRP

1. Designates the total traveled distance to minimize accordance with the set of system constraints.

$$Minimize f(x) = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d_{ij}x_{ij}^{k}$$

2. Impose that each node is visited only once by a vehicle.

$$\sum_{k=1}^{m}\sum_{i=0}^{n} x_{ij}^{k} = 1 \; j = 0, \dots, i-1, i+1, \dots, n$$

3. Ensure that continuity of vehicles are pathways.

$$\sum_{i=0}^{n} x_{ij}^{k} - \sum_{j=0}^{n} x_{ij}^{k} = 0 \;\; k = 1, \dots, m, i \neq j \;\; t = 0, \dots, n$$

4. Enforce the capacity constraint of the vehicles

$$\sum_{j=0}^{n} D_j \left(\sum_{i=0}^{n} x_{ij}^{k} \right) \leq C \; k = 1, \dots, m, i \neq j$$

5. Ensure vehicles start and finish at the depot

$$\sum_{j=0}^{n} x_{0j}^{k} \leq 1 \;\; k = 1, \dots, m$$

else

$$\sum_{i=0}^{n} x_{0i}^{k} \leq 1 \;\; k = 1, \dots, m$$

6. Discard vehicles sub-tours

$$\sum_{i,j \in S} x_{ij}^{k} \leq |S| - 1 \; S \subseteq \{2, \dots, n\}, k = 1, \dots, m$$

III. DSS Design

The DSS we design is based on SWA that first defined clusters of any agents before producing the optimal route solution or either the amounts of vehicles. For the business process of the system, we illustrate our design in form of information system framework as shown in Figure 1 below.

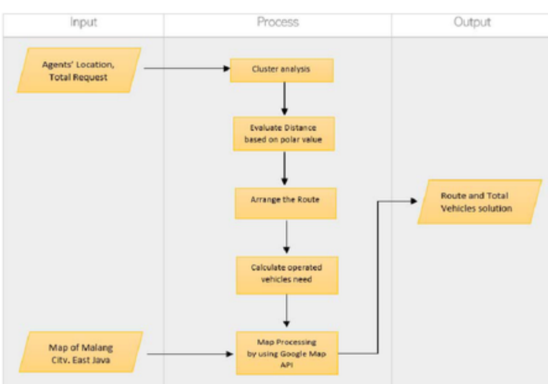

Figure 1. Information System Framework

The process starts by inputting agents' locations and total requests of each those agents. When these data provided, locations of the agents that have been set before are analyzed to find the cluster of it. Since it found, distance is calculated by a considered polar angel to arrange the route solution. Defined the amounts of vehicles need based on cluster demands is the next step of its process, before stepping to the output of the program which is visualizing route and total vehicles need by using map.

IV. Sweep Algorithm (SWA) Approach

The original SWA presented by Gillet and Miller [8] was including complicated inter-route improving steps, however, in this paper, we consider only its basic version without any inter-route improvement. This is owing to the SWA known as construction algorithm and several studies including [3] [9] use this version.

Algorithm 1 The Sweep Algorithm

Step 0. The polar angle between each stop and the depot is computed.
Sort stops in the augmentative way of polar angle (counter-clockwise direction): $s_1, s_2, s_3, \dots s_n$.
Set $k=1$.

Step 1. Insertion order is $s_k, s_{k+1}, s_{k+1}, , \dots s_n, s_1, s_2, \dots, s_{k-1}$.

Step 2. Chose obsolete vehicle.

Step 3. Continue to assign unlined stops to the vehicle according to the insertion order and construct a route while the sum of the demand stops does not meet-exceed the capacity of the vehicle.

Step 4. If an unlined stop is happening, go to step 2.
Else, go to step 5.

Step 5. Optimize each route using 2-opt edge exchange.
Record a solution.

Step 6. If $k<n$, set $k+1$ and go to step 1.
Else, go to step 7.

Step 7. Repeat step 0 – step 6 with the decreasing order of the polar angles (clockwise direction).

Step 8. Return the solution with minimum travel distance.

V. A Real Case Study: PT. Pertamina Depo Malang

Concerning to experiment the expected design of DSS, we employ it for a company that serves distribution of premium in the city of Malang, East Java Province, Indonesia. We documented 15 agents' orders within the address area (shown in Table I), utilizing 10 vehicles with the capacity of each are 24-kiloliters. All agents have particular total demands and time request which don't have specific schedules.

Based on locations of agents, we analyzed the polar coordinates to generate the cluster of every agents' points. The clustered polar coordinates are illustrated in Figure 2.

Furthermore, to create an initial route, we calculate distance metrics (shown in Table II) build of distance between one location to other locations. For introductory of vehicles need, we calculate total demands of each cluster found on average demands per agents using the formula: $t = \frac{s}{v}$ which t is time travel (minute), s is the distance (km), and v is speed (km/h).

TABLE I. DEPOT AND AGENTS' COORDINATES

Rank	Name	Longitude (x)	Latitude (y)	Average Demand/Request (kilo liters)
0	Depot	112.628333	-7.993729	-
1	Jl. Tlogomas	112.602923	-7.931374	37
2	Jl. Sukarno – Hatta	112.627474	-7.937646	29
3	Jl. S. Supriyadi	112.619700	-7.995333	29
4	Jl. R. Langsep	112.614608	-7.983133	25
5	Jl. Kol. Sugiono Gadang	112.627730	-8.016334	16
6	Jl. Trunojoyo	112.637443	-7.980579	14
7	Jl. Yulius Usman Sawahan	112.626640	-7.986138	22
8	Jl. Bandung	112.624072	-7.961933	26
9	Jl. Bend. Sutami	112.613377	-7.957075	21
10	Jl. Ki. Ageng Gribig	112.657705	-7.985239	15
11	Ds. Lowokdoro	112.627091	-8.031011	8
12	Jl. Mayjend Wiyono	112.645498	-7.978031	27
13	Jl. Mayjend Sungkono	112.642764	-8.037420	13
14	Jl Puncak Tidar	112.603089	-7.964186	22
15	Jl. Raya Dadap Rejo	112.600780	-7.898000	15

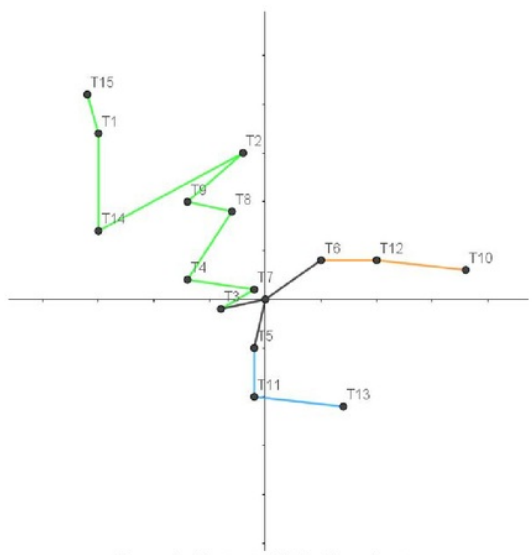

Figure 2. Illustrated Polar Coordinates

TABLE II. AGENTS' MATRIX

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0		13	10	2	3	4	2	1	5	6	4	6	4	8	6	17
1	13		5	8	6	11	8	8	5	3	11	13	9	15	5	8
2	10	5		8	7	10	6	7	4	4	9	12	6	13	7	7
3	2	8	8		2	5	4	1	5	5	6	5	5	7	5	15
4	3	6	7	2		6	4	2	4	3	5	7	5	9	3	13
5	4	11	10	5	6		4	4	8	8	6	2	5	4	8	18
6	2	8	6	4	4	4		2	4	5	4	9	1	7	5	14
7	1	8	7	1	2	4	2		3	5	4	6	3	8	5	15
8	5	5	4	5	4	8	4	3		2	7	9	5	11	3	11
9	6	3	4	5	3	8	5	5	2		8	10	6	12	2	9
10	4	11	9	6	5	6	4	4	7	8		8	4	6	9	16
11	6	13	12	5	7	2	9	6	9	10	8		8	2	10	20
12	4	9	6	5	5	5	1	3	5	6	4	8		8	6	14
13	8	15	13	7	9	4	7	8	11	12	6	2	8		12	21
14	6	5	7	5	3	8	5	5	3	2	9	10	6	12		12
15	17	8	7	15	13	18	14	15	11	9	16	20	14	21	12	

Currently PT. Pertamina depo Malang has 6 routes to delivers premium for 15 agents by utilizing 10 vehicles and achieving 95-kilometers.

PT. Pertamina depo Malang transporting premium by visiting all agents' locations in 3 stages of departure every day. They operate all available vehicles with the full capacity of it, to visit 6 routes (a route more than an agent) in stage 1, visiting 5 routes in stage 2, and then last 5 routes in the last stage. This scenario of distribution was unscheduled, so we can say it as extravagant process.

The deliberate operational procedure of the ongoing process to distributing premium from the depot to several agents of PT. Pertamina Depo Malang, we proposed DSS that able to optimize the route and amounts of vehicles used.

Using DSS is changing operation scenario delivers which sending premium from the depot according to request of agents and routes are generated based on cluster location.

Projected steps appropriate with sweep algorithm to solve CVRP model are defined as follows (Figure 3).

1. Vehicles start from depot which is PT. Pertamina depo Malang carrying the maximum capacity of premium (24-kiloliters).
2. Vehicles move to fulfill the request of the third cluster as the first visit since it has the biggest total agent of the other clusters.
3. After all agents in cluster 1st visited, vehicles arrange to accomplish the second cluster demand.

   If there is no demanded premium of any agents' in this cluster, commensurate with first cluster, vehicles are going to next cluster.
4. The last cluster to be visited is third cluster.

In case of not all agents in a cluster demanding premium supply, the first agent on a cluster to be visited will be calculated by polar angles. For instance, the 3rd cluster that has 3 agents, however someday only 2 agents need supplies of premium which are agent 11 and 13, so those polar angels of agents are computed to determine the smallest distance from the depot, the smaller the distance the sooner vehicles to be organized.

VI. Result and Conclusion

Considerable research on CVRP model using SWA has been made in the past. However, most of the papers have focused on optimizing the route of vehicles to minimize operational cost [4][5]. For the past research, Nurcahyo [5] able to reduce current vehicles' operational route by 34% shorter. The other problem for reducing cost of vehicles operation is amounts of vehicles used [6]. Former research by Suthikarnnarunai [6], this algorithm capable of trimming total vehicles used for 15% from the original subject need.

The total distance that we gain by this method is 60-kilometers for 319-kiloliters of agents' demands. The First cluster has 37-kiloliters amount of request by the total distance 8-kilometers for 3 agents. Then the second cluster has 56-kiloliters amount of request by total travel distance 7-kilometers for 3 agents. For the last cluster, which the third cluster having the biggest total demand since it carrying 9 agents with total demand for premium are 226-kiloliters and whole distance travel are 45-kilometers.

According to this result, we found that our design DSS method is accomplishing to reduce both total distance and amounts of vehicles. total distance is compressing 37 percent, while amounts of vehicles used are abbreviating 15 percent. Hence, we believe that our DSS design can be implemented to typical problem of distributing premium.

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