ROUTE OPTIMIZATION IN ASYMMETRIC CAPACITATED VEHICLE ROUTING PROBLEM (ACVRP) MODEL USING TABU SEARCH ALGORITHM
(Case Study: Car Oil Distribution of PT. Kencana Central Mobil)

Thedorus Junjun[1)]
Mariatul Kiftiah[2)]
Fransiskus Fran[3)]
[1,2,3)]Mathematics Study Program, Faculty of Mathematics and Natural Sciences, Universitas Tanjungpura, Pontianak, Indonesia
e-mail: fransiskusfran@math.untan.ac.id

ABSTRACT

PT. Kencana Central Mobil is an automotive workshop that distributes oil to nine regular customers spread across Pontianak and its surroundings. The route from the depot to the customer and between customers has a different length, because when making a round trip using different roads. From this information, the author conducted observations in the field to measure the distance between customers with the help of the Avanza application. Thus, the problem in this company is included in the Asymmetric Capacitated Vehicle Routing Problem. The ACVRP model is a problem where the route from location i to j is not the same as the route from location j to i. Based on the problems that have been explained, this study uses the Tabu Search algorithm to solve it. The Tabu Search algorithm works by moving from one route to another, so that when related to a problem the company can find a trip by choosing the shortest route. There are six steps in solving this problem, namely determining the initial route, finding alternative routes by swapping two node positions so that the routes that can be formed each iteration are $C_2^9 = 36$ routes (nine is the number of customers), choosing the best route among alternative routes, determining the new best route, updating the tabu list and checking the stopping criteria. From the calculation results, there is a difference in the distance traveled from the initial route which is 63.16 km long, while when calculated using the Tabu Search Algorithm, it can be seen that the tabu search criteria stops at the 7th iteration with a route length of 50.26 km so that it differs by 12.9 km from the initial route. The length of the route is optimal because it has the shortest route length of all the literature that has been traced.

Keywords: Distance, Asymmetric, Heuristic Methods.

INTRODUCTION

Transportation is a major component in the progress of a country, because transportation can facilitate economic development and community development. Thus, making transportation the most important element in human life (Fatimah, 2019). One of the efforts that can be made by companies to reduce transportation costs and improve good service, it is necessary to find the shortest route in distributing goods to customers. Based on the problems that have been described, the case at the company is a Vehicle Routing Problem (VRP). The VRP model is a problem of determining the optimal route in distributing goods or services to different customers with the known demand of each customer (Addini's & Fauzan, 2018). Among the many transportation aspect problems, Vehicle Routing Problem (VRP) is considered one of the most important problems in joint operational decision making. In general, VRP solves the types of problems that customers face and need to be served across multiple routes through at the lowest possible cost for operational purposes (Moghadi et al., 2020). There are several types of VRP, one of which is the Capacitated Vehicle Routing Problem (CVRP). The CVRP model is an optimization problem that finds travel routes with limited capacity vehicles. Travel costs between locations are known and can be asymmetric or symmetrical (Alesiani et al., 2021). The CVRP model has a special case where a distance between two vertices is not always the same in every direction, in other words, the distance from vertex i to vertex j is different from the distance from vertex j to vertex i which is called the Asymmetric Capacitated Vehicle Routing Problem (ACVRP).

The Tabu search algorithm is an optimization problem solver that utilizes short-term memory to prevent the search process from being trapped in the local optimum so as not to re-search the solution space that has been previously examined (Togatorop et al., 2022), this algorithm works by swapping the order of nodes (Uman et al., 2021), research related to the tabu search algorithm has been carried out by several studies, including determining the shortest route for distributing 3 kg LPG gas carried out by PT. Fega Palu Pratama (Riswan et al., 2020), solving the traveling salesman problem at PT. XX (Fatmawati et al., 2015), assignment of distribution routes at the Lhokseumawe branch of PT Yakult Indonesia Persada (Ritonga et al., 2021), determination of mineral water distribution routes in the special area of Yogyakarta (Firdaus & Rahayu, 2018), production scheduling of PT Arkha Jayanti Persada to minimize the makespan value (Falih, 2021), implementation of graph coloring in nurse work scheduling (Sari et al., 2023), other research related to the ACVRP model is a metaheuristic solution to the asymmetric capacitated vehicle routing problem model (Leggieri & Haouari, 2018), solution-based tabu search for the capacitated dispersion problem (Lu et al., 2023), a tabu search algorithm for the probabilistic orienteering probelm (Chou et al., 2020).

PT Kencana Central Mobil is a business owned by a company engaged in the sale of workshop goods. This company has several customers spread across Pontianak City and its surroundings, where these customers always buy their workshop business needs at this company. One of the items purchased by customers is Mobil 1 branded vehicle oil. Oil is one of the main parts of a vehicle, because oil is the determination of the performance and strength of the vehicle engine. The main function of oil is to lubricate and reduce friction between engine parts so that the vehicle is not easily damaged (Purba & Tarigan, 2020).

In meeting customer demand, PT Kencana Central Mobil must be able to distribute ordered goods with the minimum possible time and find the shortest route. At present, the car oil distribution mechanism carried out by PT Kencana Central Mobil by delivering oil using a box car from one customer to another, according to the number of requests from customers. Travel routes between two places (for example, depot to customer a) have different route lengths because when traveling through different roads. Thus, causing the problem at PT Kencana Central Mobil to be included in ACVRP. Based on the statement that has been explained, this article focuses on finding the shortest route that can be taken so as to minimize travel time. The limitation in this study is the data obtained from PT Kencana Central Mobil. The data consists of regular customers, oil brands used, number of depots and vehicles, and traffic density and road conditions are ignored. The Tabu Search algorithm has also been studied by Hakim et al. (2023) discussing the VRP case of designing transportation routes using 5 vehicles and considering the time window during distribution, if it exceeds the time window then the product will be returned to the depot and will be sent the next day. While the research discussed by the author regarding the distribution of oil using 1 vehicle and does not consider the time window during distribution.

METHOD

The data used in this study are primary data, namely the results of interviews with the SVP of PT Kencana Central Mobil regarding the distribution of car oil to nine regular customers spread across Pontianak City and its surroundings. The data includes the depot address, customer address, number of requests for each customer, and the type and capacity of the vehicle used. Furthermore, from the data that has been collected, the author conducted direct observations in the field to measure the distance from the depot to the customer and between customers with the help of the Avenza Maps application, this application helps the author to measure the distance between one customer and another. From this data, the author uses the Tabu Search Algorithm to solve it because with this algorithm it can find the shortest distance by using the exchange of two nodes.

Asymmetric Capacitated Vehicle Routing Problem (ACVRP)

Vehicle Routing Problem (VRP) is a management of the distribution of goods using vehicles with respect to service, and a group of customers. The solution of VRP is to determine the various routes traveled by vehicles that start and end at the depot. Thus, all customer needs will be met and operational problems can be solved with minimal transportation costs (Kusumawardana & Irhamah, 2013). There are many types of VRP models, one of which is CVRP. The CVRP model is one of the optimization problems in VRP for a number of vehicles with limited capacity constraints (Sulistiono & Mussafi, 2015).

The ACVRP model is a development of CVRP. In general, ACVRP is the problem of a travel route from vertex i to j is not the same as the travel route from vertex j to i so that the distance matrix obtained is asymmetric (Togatorop et al., 2022), so the only difference between ACVRP and CVRP is the asymmetric distance matrix. ACVRP can be defined on a directed graph written as $G = (V, E)$ where $V = \{0,1, \dots, n\}$ is the set of vertices and E is the set of edges. The set $C = \{1,2, \dots, n\}$ denotes the customers such that $C \subset V$, and each demand vertex $d_C \geq 0$. Vertex v_0 represents a depot with demand $d_0 = 0$. The non-empty set K is the set whose members are the available vehicles, all vehicles have equal carrying capacity $Q > 0$, c_{ij} is the non-negative cost or distance with edge $(i, j) \in E$ and $c_{ii} = 0$, for each i $i \in V$. The asymmetric distance matrix is calculated using the actual distance between a pair of vertices i, j with $c_{ij} \neq c_{ji}$ (Siswanto et al., 2019).

Define the decision variables:

$$x_{ij} = \begin{cases} 1, \text{If a vehicle travels from node } i \text{ to node } j \\ 0, \text{If the vehicle does not travel from node } i \text{ to node } j \end{cases}$$

The formulation is as follows:

Objective function

$$Min\ Z = \sum_{i \in V} \sum_{j \in V} c_{ij} x_{ij} \tag{1}$$

with constraints

a. Each customer is visited once, has one start node and one end node

$$\sum_{i \in V} x_{ij} = 1 \quad \text{for each } \ j \in V \backslash \{0\}.$$

b. Each customer is visited once, has one end node and one start node

$$\sum_{j\in V} x_{ij} = 1 \text{ for each } i \in V\backslash\{0\}.$$

c. The number of vehicles used does not exceed the number of vehicles available

$$\sum_{i\in V} x_{i0} \leq K.$$

d. The number of vehicles leaving the depot is equal to the number of vehicles returning to the depot

$$\sum_{i\in V} x_{i0} = \sum_{j\in V} x_{0j} \ .$$

e. The decision variable x_{ij} is a binary integer

$$x_{ij} \in \{0,1\} \text{ for each } i,j \in V.$$

Description

Z : Objective function to minimize the travel distance from i to j

x_{ij} : Travel route from node i to node j

c_{ij} : Distance from vertex i to vertex j

C : Customer

K : Vehicle

V : Set $V = \{0,1,\dots,n\}$ where 0 denotes depot and $1,\dots,n$ denotes customer.

Tabu Search Algorithm

Tabu search algorithm is an optimization problem solving to search the state space of a problem repeatedly by using short-term memory strategies to avoid being trapped in a local optimum. The basic goal of the Tabu Search Algorithm is to prevent repeated cycles of previously found solutions by using a memory structure that has recorded the search process that has been carried out (Candra, 2016).

The Tabu Search algorithm has several basic components that are used to solve the ACVRP problem, including (Sulistiono & Mussafi, 2015):

a. Route Representation: a sequence of nodes, where each node appears only once in the sequence except for depots appearing twice, the nodes are represented as depots and customers.
b. Initial Solution: An initial route can be formed using heuristic techniques by looking for nodes adjacent to the depot and adding the route as long as it does not form a cycle, so that all nodes are visited which will be fixed in the next iteration.
c. Neighborhood Structure: Alternative routes are obtained by exchanging two vertices in one route using the heuristic method of Exchange.
d. Taboo List: the taboo list contains a sequence of vertices with the shortest route that has been found in the previous iteration, the attribute of the vertex is the order of visits between vertices that have the shortest route that has been searched at each iteration. The length of the tabu list size will increase proportional to the number of problems.
e. Aspiration Criteria: a technique to cancel the taboo status. This happens when there is a new route in the neighborhood that is better than the previously obtained route, then the new route is included in the taboo list as the new best route and the taboo status is revoked.
f. Termination Criteria: a method used to stop tabu search.

The tabu search will stop if it meets one of the following criteria:

1. After the iteration reaches the maximum, which corresponds to the number of customers.
2. After several iterations, there is no change in the value of the objective function.
3. When the objective function reaches the predefined upper limit value or lower limit value.
4. When no more new routes can be generated through the neighborhood where all moves (exchanges) are already in the taboo list.

The steps taken in solving the ACVRP problem using the Tabu Search Algorithm (Riswan et al., 2019):

Step 1: Determine the initial route as the optimal route at the 0th iteration. The initial route is formed by finding a vertex close to the depot and adding the closest vertex to the previous vertex to the route. This is done for all vertices until all vertices are visited.

Step 2: Search for alternative routes and find the next iteration. Exchanging the positions of two vertices based on the route will generate an alternative route.

Step 3: Selecting the shortest route among the alternative routes obtained in Step 2.

Step 4: If the value of the shortest route in Step 2 is smaller than the value of the initial optimal route, then the route can be selected as the new optimal route.

Step 5: Update the tabu list by adding the optimal route obtained in Step 4.

Step 6: If the stop criterion is met, then the process stops. Otherwise, the search process will be repeated starting from Step 2 and will stop when the stopping criteria are met

RESULTS AND DISCUSSION

In this study, the data used is in the form of car oil distribution by PT Kencana Central Mobil which is measured directly to the field assisted by the Avenza Maps application in units of km. As for the calculations in this study, they were carried out manually by adding the length of the route to be passed. The following is presented in Table 1 regarding the distribution of car oil to nine customers spread across Pontianak City and its surroundings.

Table 1. Distance from depot to customer and between customers (km)

	v_0	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9
v_0	0	7.6	6.18	3.28	0.77	14.1	8.54	3.91	3.99	11.59
v_1	7.65	0	13.83	5.22	5.87	6.86	3.5	8.73	10.94	4.17
v_2	6.8	13.83	0	7.94	6.95	17.31	13.87	4.31	6.31	14.62
v_3	2.78	5.04	8.96	0	1.9	11.9	5.98	3.88	6.49	9.15
v_4	0.77	7.01	6.95	2.75	0	13.87	8.06	4.15	4.76	12.83
v_5	14.21	7.35	17.31	11.77	13.35	0	10.22	13	18.18	2.69
v_6	8.91	3.03	15.09	6.47	7.3	9.88	0	9.89	9.5	7.19
v_7	3.91	8.62	4.31	3.62	4.15	13	9.56	0	8.02	10.31
v_8	3.99	10.87	6.31	6.58	4.76	18.25	9.5	7.88	0	15.56
v_9	11.52	4.66	14.62	9.08	11.96	2.69	7.53	10.31	15.49	0

Where

v_0 : Urai Bawadi Street, No.115B (Depot)

v_1 : Arteri Supadio Street, No.5-7B Sungai Raya (RND Workshop)

v_2 : Kom. Yos Sudarso Street, Tri Dharma Alley, No.17 (Aneka Jaya Motors)

v_3 : Letjen S. Parman Street, Villa Palma Residence, No. A6 (PRW Sports Motorbike)

v_4 : Putri Candramidi (Podomoro) Street, Sentosa Alley, No. 25A (Hoki Motors)

v_5 : Adisucipto Street, Teluk Mulus Residence, No. A8 (HRP Workshop)

v_6 : Parit H. Husin II Street, Pesona Mutiara Dewata Residence (Peak Auto Car)

v_7 : Kom. Yos Sudarso Street, No.136G (HDR Car Workshop)

v_8 : Ampera Street (next to pesona Ampera Alley) (New Energy Workshop)

v_9 : Adisucipto Street (in front of Santo Yusup Pontianak Carpentry Vacational School) (Car Partner)

An illustration of the journey graph from depot to customer and between customers is presented in Figure 1.

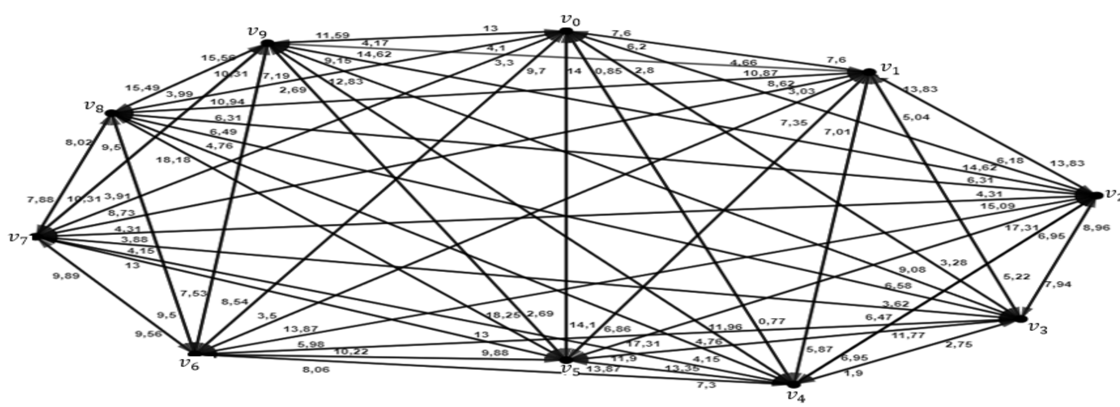

Figure 1. Illustration of car oil distribution journey graph

Calculation Process of Tabu Search Algorithm Application on ACVRP Model

The following describes the ACVRP model which consists of decision variables, objective function and constraint function which is a linear programming problem.

1) Decision Variable

   The decision variable in this study is whether or not there is a vehicle running on route x_{ij}. If there is then it is worth 1 and if there is no value 0 with $i, j \in \{v_0, v_1, \ldots, v_9\}$.

2) Objective Function

   The purpose of this research is route optimization, so as to obtain the shortest route in distributing car oil. Based on interviews that have been conducted, the usual route in distributing car oil to customers is $v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$ so that the route length is obtained as follows:

$$Min\ Z = \sum_{i=0}^{9}\sum_{j=0}^{9} c_{ij}x_{ij}$$

$$\begin{aligned} Min\ Z &= 6.8x_{02} + 10.87x_{19} + 4.31x_{27} + 2.75x_{34} + 4.76x_{48} + 14.1x_{50} + 3.5x_{61} + \\ &\quad 3.88x_{73} + 9.5x_{86} + 2.69x_{95} \\ &= 63.16 \end{aligned}$$

So that the initial route length is 63.16 km.

3) Constraint Function

There are several obstacles related to this research, namely:

a) Each customer is visited once, has one start node and one end node

$$\sum_{i=0}^{9} x_{ij} = 1 \quad \text{for each } \ j \in V\backslash\{0\}$$

b) Each customer is visited once, has one end node and one start node

$$\sum_{j=0}^{9} x_{ij} = 1 \quad \text{for each } \ i \in V\backslash\{0\}$$

c) The number of vehicles used does not exceed the number of vehicles available

$$\sum_{i=0}^{9} x_{i0} \le 1$$

d) The number of vehicles leaving the depot is equal to the number of vehicles returning to the depot

$$\sum_{i=0}^{9} x_{i0} = \sum_{j=0}^{9} x_{0j}$$

e) The decision variable x_{ij} is a binary integer

$$x_{ij} \in \{0,1\} \quad \text{for each } i,j \in V$$

Based on the objective function so as to obtain a taboo list at the 0th iteration to get another alternative route

Table 2. 0th iteration tabu list

Iteration to	Route	Route length (km)
0	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	63.16

Table 2 states the initial travel route and route length taken by the box car in distributing car oil to customers. The travel route in the 0th iteration is selected as the next process to find alternative routes by exchanging two node positions. Here is how to find alternative routes in the 1st iteration in Table 3.

Table 3. Node swap for the 1st iteration

Iteration to	Route	Route length (km)
1	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	59.14
2	$v_0 - v_3 - v_7 - v_2 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	56.87
3	$v_0 - v_4 - v_7 - v_3 - v_2 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	57.5
4	$v_0 - v_8 - v_7 - v_3 - v_4 - v_2 - v_6 - v_1 - v_9 - v_5 - v_0$	65.63
5	$v_0 - v_6 - v_7 - v_3 - v_4 - v_8 - v_2 - v_1 - v_9 - v_5 - v_0$	71.45
6	$v_0 - v_1 - v_7 - v_3 - v_4 - v_8 - v_6 - v_2 - v_9 - v_5 - v_0$	82.44
7	$v_0 - v_9 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_2 - v_5 - v_0$	91.46
8	$v_0 - v_5 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_2 - v_0$	77.06
9	$v_0 - v_2 - v_3 - v_7 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	62.74
10	$v_0 - v_2 - v_4 - v_3 - v_7 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	61.6
11	$v_0 - v_2 - v_8 - v_3 - v_4 - v_7 - v_6 - v_1 - v_9 - v_5 - v_0$	61.34
12	$v_0 - v_2 - v_6 - v_3 - v_4 - v_8 - v_6 - v_7 - v_9 - v_5 - v_0$	73.58
13	$v_0 - v_2 - v_1 - v_3 - v_4 - v_8 - v_6 - v_7 - v_9 - v_5 - v_0$	79.34
14	$v_0 - v_2 - v_9 - v_3 - v_4 - v_8 - v_6 - v_1 - v_7 - v_5 - v_0$	86.7
15	$v_0 - v_2 - v_5 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_7 - v_0$	75.4
16	$v_0 - v_2 - v_7 - v_4 - v_3 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	58.19
17	$v_0 - v_2 - v_7 - v_8 - v_4 - v_3 - v_6 - v_1 - v_9 - v_5 - v_0$	57.07
18	$v_0 - v_2 - v_7 - v_6 - v_4 - v_8 - v_3 - v_1 - v_9 - v_5 - v_0$	66.98
19	$v_0 - v_2 - v_7 - v_1 - v_4 - v_8 - v_6 - v_3 - v_9 - v_5 - v_0$	72.96
20	$v_0 - v_2 - v_7 - v_9 - v_4 - v_8 - v_6 - v_1 - v_3 - v_5 - v_0$	82.92
21	$v_0 - v_2 - v_7 - v_5 - v_4 - v_8 - v_6 - v_1 - v_9 - v_3 - v_0$	72.83
22	$v_0 - v_2 - v_7 - v_3 - v_8 - v_4 - v_6 - v_1 - v_9 - v_5 - v_0$	58.58
23	$v_0 - v_2 - v_7 - v_3 - v_6 - v_8 - v_4 - v_1 - v_9 - v_5 - v_0$	63.04
24	$v_0 - v_2 - v_7 - v_3 - v_1 - v_8 - v_6 - v_4 - v_9 - v_5 - v_0$	77.39
25	$v_0 - v_2 - v_7 - v_3 - v_9 - v_8 - v_6 - v_1 - v_4 - v_5 - v_0$	87.09
26	$v_0 - v_2 - v_7 - v_3 - v_5 - v_8 - v_6 - v_1 - v_9 - v_4 - v_0$	76.27
27	$v_0 - v_2 - v_7 - v_3 - v_4 - v_6 - v_8 - v_1 - v_9 - v_5 - v_0$	66.93
28	$v_0 - v_2 - v_7 - v_3 - v_4 - v_1 - v_6 - v_8 - v_9 - v_5 - v_0$	68.42
29	$v_0 - v_2 - v_7 - v_3 - v_4 - v_9 - v_6 - v_1 - v_8 - v_5 - v_0$	83.95
30	$v_0 - v_2 - v_7 - v_3 - v_4 - v_5 - v_6 - v_1 - v_9 - v_8 - v_0$	68.68
31	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_1 - v_6 - v_9 - v_5 - v_0$	60.79
32	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_9 - v_1 - v_6 - v_5 - v_0$	70.07
33	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_5 - v_1 - v_9 - v_6 - v_0$	67.93
34	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_9 - v_1 - v_5 - v_0$	64.67
35	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_5 - v_9 - v_1 - v_0$	$\mathbf{56.48}$
36	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_5 - v_9 - v_0$	59,64

In Table 3 are the alternative routes obtained from exchanging two node positions. One of all alternative routes is selected with the shortest route length for the next process. So that the 35th route is obtained which is the shortest route with a route length of 56.48 km, therefore, the route is for the next process and is included in the taboo list. Because the length of the route is smaller than the 0th iteration, so the route is chosen as the new optimum.

Table 4. 1st iteration tabu list

Iteration to	Route	Route length (km)
0	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	63.16
1	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_5 - v_9 - v_1 - v_0$	56.48

Table 4 states the 1st iteration tabu list which is a list of shortest routes obtained during the search in the 1st iteration. The tabu search is carried out continuously following the method in the 1st iteration, until it meets the stopping criteria. Based on the calculations carried out, the stopping criteria stop at the 9th iteration with the following tabu list:

Table 5. 9th iteration tabu list

Iteration to	Route	Route length (km)
0	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_1 - v_9 - v_5 - v_0$	63.16
1	$v_0 - v_2 - v_7 - v_3 - v_4 - v_8 - v_6 - v_5 - v_9 - v_1 - v_0$	56.48
2	$v_0 - v_3 - v_7 - v_2 - v_4 - v_8 - v_6 - v_5 - v_9 - v_1 - v_0$	56.6
3	$v_0 - v_3 - v_7 - v_2 - v_8 - v_4 - v_6 - v_5 - v_9 - v_1 - v_0$	53.76
4	$v_0 - v_4 - v_7 - v_2 - v_8 - v_3 - v_6 - v_5 - v_9 - v_1 - v_0$	53.18
5	$v_0 - v_4 - v_7 - v_2 - v_8 - v_3 - v_1 - v_5 - v_9 - v_6 - v_0$	53.02
6	$v_0 - v_4 - v_7 - v_2 - v_8 - v_6 - v_1 - v_5 - v_9 - v_3 - v_0$	51.01
7	$v_0 - v_4 - v_7 - v_2 - v_8 - v_7 - v_9 - v_5 - v_1 - v_3 - v_0$	50.26
8	$v_0 - v_4 - v_7 - v_2 - v_8 - v_6 - v_5 - v_9 - v_1 - v_3 - v_0$	50.44
9	$v_0 - v_4 - v_7 - v_2 - v_8 - v_6 - v_9 - v_5 - v_1 - v_3 - v_0$	50.44

Based on Table 5, the stopping criteria have been met, namely until the maximum iteration reaches the number of customers, namely nine customers used in the node exchange. From the calculation results using the Tabu Search Algorithm, the shortest route is 50.26 km long at the 7th iteration with the travel route $v_0 - v_4 - v_7 - v_2 - v_8 - v_7 - v_9 - v_5 - v_1 - v_3 - v_0$. From this research, there is a difference in the length of the route traveled from the initial route with the Tabu Search Algorithm. The length of the initial route traveled by PT Kencana Central Mobil in distributing car oil is 63.16 km, while when using the Tabu Search Algorithm is 50.26 km, thus cutting the route length by 12.6 km. The following is a route map that can be traveled based on the calculation results.

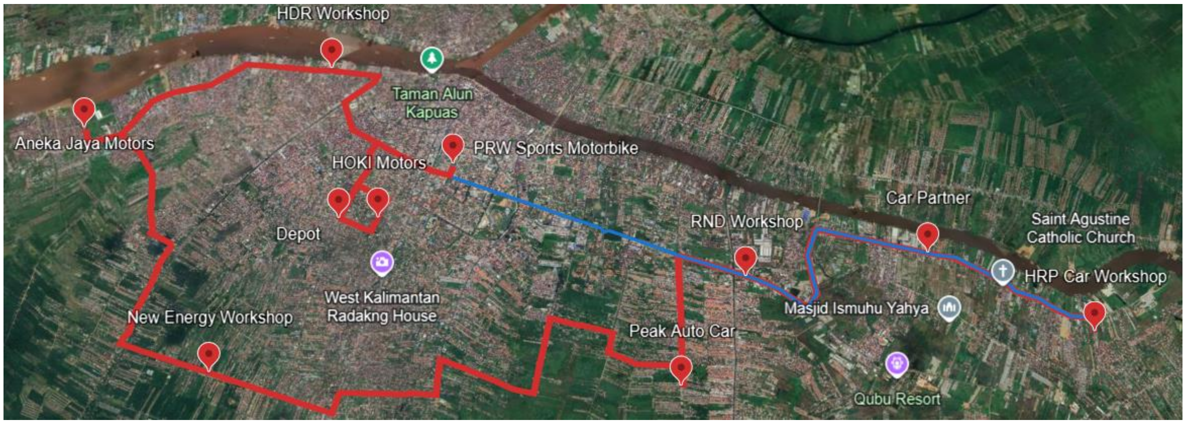

Figure 2. Shortest alternative route

Based on Figure 2, there are red and blue colors that explain the travel route that can be taken by box cars in distributing car oil to customers, where the red color is the travel route from road Then continued with road Letjen S. Parman Complex Ruko Villa Palma No.A6 (PRW Motor Sport) - road Urai Bawadi No.115B (Depot). While the blue route with the travel route road Adisucipto Perumahan Teluk Mulus No.8 (HRP Car Workshop) - road Arteri Supadio No.5-7B Sungai Raya (RND Workshop) - road Letjen S. Parman Complex Ruko Villa Palma No.A6 (PRW Sports Motorbike). With this map, it is hoped that PT. Kencana Central Mobil can use it to minimize time in the distribution process

CONCLUSION

Based on calculations using the Tabu Search Algorithm, the shortest route that can be traveled by PT Kencana Central Mobil is 50.26 km at the 7th iteration. The travel routes are $v_0 - v_4 - v_7 - v_2 - v_8 - v_7 - v_9 - v_5 - v_1 - v_3 - v_0$. The author's suggestion for further researchers is to use as much data as possible to see the accuracy of this Algorithm, further researchers can also limit customers so that they only take customers who are close to the depot.

REFERENCE

Addini's, S. S. F., & Fauzan, M. (2018). Penyelesaian Masalah Rute Terpendek Distribusi Kertas di CV. Margotama Fancindo Yogyakarta Menggunakan Metode Nearest Neighbour dan Metode Saving Matrix. *Jurnal Kajian dan Terapan Matematika*, *7*(3), 96–106.

Alesiani, F., Ermis, G., & Gkiotsalitis, K. (2022) Constrained Clustering For The Capacitated Vehilce Routing Problem (CC-CVRP). *Appliend Artifical Intelligence*. *36(1*), 1995658.

Candra, L. (2016). Penerapan Algoritma Tabu Search untuk Penjadwalan Mata Pelajaran di SMK Swasta Pelita-2 Aekkanopan. *JURIKOM (Jurnal Riset Komputer)*, *3*(6), 74–79.

Chou, X., Gambardella L. M. & Montemanni, R. (2021). A Tabu search algorithm for the probabilistic orienteering problem. *Computers & Operations Research*, *126*, 105107

Falih, M. H. N. (2021). Implementasi Algoritma Tabu Search dalam Penjadwalan Produksi PT Arkha Jayanti Persada untuk Meminimasi Nilai Makespan. *Scientific Journal of Industrial Engineering*, *2*(2), 41–46.

Fatimah, S. (2019). *Pengantar Transportasi*. Myria Publisher.

Fatmawati, Prihandono, B., & Noviani, E. (2015). Penyelesaian Travelling Salesman Problem dengan

Metode Tabu Search. *Bimaster*, *04*(1), 17–24.

Firdaus, A. N., & Rahayu, P. P. (2018). Aplikasi Algoritma Tabu Search dan Safety Stock pada Penentuan Rute Distribusi Air Mineral di Daerah Istimewa Yogyakarta. *Jurnal Fourier*, *7*(1), 45–56.

Hakim, Lidia A., Ardiansyah, Muhammad N., & Yulianti, Femi. (2023). Usulan Perancangan Rute Transportasi di PT. XYZ Menggunakan Algoritma Tabu Search Pada Heterogeneous Fleet Vehicle Routing Problem dengan Time Window untuk Meminimasi Biaya Transportasi. *e-Proceeding of Engineering*. 10(3), 3055-3062.

Kusumawardana, A. S. & Irhamah. (2013). Vehicle Routing Problem With Stochastic Demands dengan Metode Hybrid Simulated Annealing-Algoritma Genetika. *Jurnal Statistika Universitas Muhammadiyah Semarang*, *1*(2), 1–8.

Leggieri, V., & Haouari, M. (2018). A Matheuristic for the Asymmetric Capacitated Vehicle Routing Problem. *Discrete Applied Mathematics*, *234*, 139–150.

Lu, Z., Martinez-Gavara, A., Hoa, J. K., & Lai, X. (2023). Solution-based tabu search for the capacitated dispersion problem. *Expert Systems with Applications, 233*, 119856.

Moghdani, R., Salimifard, K., Demir, E., & Benyettou, A. (2021). The green vehicle routing problem: A systematic literature review. *Journal of Cleaner Production*, *279*, 123691.

Purba, R., & Tarigan, K. (2020). Pengaruh Jenis Oli Terhadap Daya dan Konsumsi Bahan Bakar Motor Kapasitas 150 CC. *Jurnal Ilmiah Teknik Sipil*, *9*(1), 47–58.

Riswan, Sahari, A., & Lusiyanti, D. (2020). Penentuan Rute Terpendek Pendistribusian Tabung Gas Lpg 3 Kg PT. Fega Gas Palu Pratama Menggunakan Algoritma Tabu Search. *Jurnal Ilmiah Matematika dan Terapan*, *16*(2), 221–229.

Ritonga, R. P., Zakaria, M., & Syukriah, S. (2021). Penugasan Rute Distribusi Menggunakan Algoritma Tabu Search pada PT. Yakult Indonesia Persada Cabang Lhokseumawe. *Industrial Engineering Journal*, *10*(1).

Sari, R. F., Rakhmawati, F., & Nur Lela. (2023). Implementasi Pewarnaan Graf Menggunakan Metode Algoritma Tabu Search Pada Penjadwalan Kerja Perawat. *G-Tech: Jurnal Teknologi Terapan*, *7*(1), 298–304.

Siswanto, B. N., Ariffien, A., & Jayakusuma, I. (2019). Sistem Routing Proses Delivery Menggunakan Simulated Annealing (Studi Kasus: PT. X). *Jurnal Teknologia*, *2*(1), 87–105.

Sulistiono, S., & Mussafi, N. S. M. (2015). Rancang Bangun Vehicle Routing Problem Menggunakan Algoritma Tabu Search. *Jurnal Fourier*, *4*(2), 113–122..

Togatorop, R. E., Puspita, F. M., Octarina, S., Yuliza, E., & Dewi, N. R. (2022). Penerapan Algoritma Tabu Search pada Model ACVRP untuk Menentukan Rute Pengangkutan Sampah yang Optimal di Kecamatan Kalidoni. *Teorema: Teori dan Riset Matematika*, *7*(2), 303–310.

Uman, M. S., Mustafis, M., & Suryono, S. (2022). A hybrid genetic algorithm and tabu search for minimizing makespan in flow shot scheduling problem. *Journal of king saud University-Computer and Information Sciences*, *34(9)*, 7459-7467.