Application of Vehicle Routing Problem to Determine Optimal Route in Fuel Distribution: A Case Study

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Abstract

As a country with quite a lot of motorized vehicle users, fuel is an important requirement for the Indonesian people. Apart from being used for transportation, fuel is also used to support various sectors. Thus, the supply of fuel is something that is vital to pay attention to, especially in relation to fuel distribution. Problems related to the distribution of fuel include making decisions regarding the distribution routes between gas stations. The choice of vehicle route will determine the total distance traveled by the fleet to create an optimal distribution system, so that route selection must be effective and efficient. This study discusses the distribution of fuel from Boyolali Fuel Terminal to gas stations in several of the residences in Surakarta and western eastern Java. Vehicle Routing Problem (VRP) is used to solve the problem and Google OR-Tools Algorithm and Python programming are used to get the minimum total distance from the fuel transport truck. The results of this study are the acquisition of a new distribution route so that the distance of transportation decreases by about 60% than before.

Keywords
Fuel, distribution route, vehicle routing problem

1. Introduction

A company must be able to optimize its distribution system in order to compete with other similar companies. One way is by optimizing transportation. One of the problems in transportation is Vehicle Routing Problems (VRP), which are designing a set of low-cost vehicle routes where each vehicle starts and ends at the depot, each consumer is only served once by a vehicle, and the total demand carried does not exceed the vehicle's capacity. This transportation contributes 1/3 to 2/3 of the total distribution cost (Toth, 2002). VRP is a problem of optimization, which relies on determining the shortest transport routes for a strictly limited number of means of transport, whose aim is to handle a set of customers located in different geographic locations while maintaining defined restrictions (Bruniecki, 2016).

The Boyolali Fuel Terminal is assigned with distributing fuel oil to refueling stations in several areas, such as South Semarang, Salatiga, Surakarta, Sragen, Boyolali, Sukoharjo Klaten, Wonogiri, Karanganyar, Purwodadi, Blora, Ngawi, Magetan and Pacitan. Boyolali Fuel Terminal distributes BBM to 238 gas stations, industry, PT KAI, PT PLN, and the TNI / POLRI. The distribution pattern of Boyolali Fuel Terminal uses a zoning system. The zoning system is based on the distance of the gas station to the Boyolali Fuel Terminal. The zoning system is divided into three, namely a distance of less than 30 km, a distance between 30 km to 60 km and a distance of more than 60 km. According to Pertamina, the zoning system is not yet optimal so that a more optimal distribution system is needed.

The development of the community's economy makes the expansion of development in various fields, so that the fuel distribution system becomes more complex. In a distribution system, one important factor to consider is the route chosen. The route chosen is the most important element in determining the distance to be traveled and the costs to be incurred. If the selected route is optimal, the distribution system will become more effective and efficient. The optimal route can minimize transportation costs incurred.

There are many variants of VRP study, depend on the condition of the company. Previous research that have been done by Sharma et al. (2018) stated that there is 14 variants of VRP, there are Capacitated Vehicle Routing Problem, Multiple Depot Vehicle Routing Problem, Periodic VRP, Split Delivery VRP, VRP With Satellite Facilities, Heterogeneous Fleet VRP, VRP with time windows, Green VRP, Generalised VRP, Stochastic VRP, Rich VRP, Open VRP, VRP with Pick-Up and Delivery, Asymmetric VRP. VRP problems can be solved with different algorithms, such as this previous research in Table 1.

Table 1. Previous Research of VRP with different algorithms

No.	Authors	Algorithms	VRP Problem
1	Skok, et.al (2000)	Genetic Algorithms	Capacitated VRP with Heuristic method
2	Surjandari, et.al (2011)	Tabu Search	Multi Compartment, Capacitated, Time Window, and Loading Unloading VRP with Heuristic method
3	Benantar and Ouafi (2012)	Tabu Search	Multi Compartment and Time Window VRP with Heuristic method
4	Battarra, et.al (2014)	Branch and Cut and Branch and Cut and Price	Cluster and Capacitated VRP with combination of Heuristic and Exact Approach
5	Reed, et.al (2014)	Ant Colony	Multi Compartment, Clustered, Capacitated, Loading Unloading VRP with Metaheuristic method
6	Marc, et.al (2015)	Genetic Algorithms (GA) and Simulated Annealing (SA)	Capacitated and Clustered VRP with Hybrid Use (Metaheuristic and Heuristic method)
7	Vidal, et.al (2015)	Iterated Local Search Algorithm dan Hybrid Genetic Search	Capacitated and Clustered VRP with Hybrid Use (Metaheuristic and Heuristic method)
8	Henke, et.al (2015)	Neighborhood Search	Multi Compartment and Capacitated VRP with Heuristic method
9	Izquierdo, et.al (2016)	Record to record travel	Capacitated and Clustered VRP with Metaheuristic method
10	Yahyaoui, et.al (2018)	Neighborhood Search and Genetic Algorithms	Multi Compartment, Clustered, and Capacitated VRP with Metaheuristic method

In this paper, we are interested by VRP with multi capacity of vechicles and stations. In VRP, if each vehicle is assigned a certain load capacity, then this problem is known as Capacitated VRP (Toth and Vigo, 2002). This research will optimize the distribution route of the TBBM Boyolali oil truck to all its refueling stations. Each oil truck used has a different capacity. Refueling stations also have individual demands. Therefore, the type of VRP that is suitable for use is CVRP. If researchers have already tried research VRPs with modeling and algorithmic approaches, practical implementation and employs programming techniques is this paper focus. We use Google OR-Tools in data processing, an optimization tool developed by Google with its own algorithm. In implementing Google OR-Tools we use Python programming language.

2. Quantitative Approach

Vehicle Routing Problem (VRP) is one of the combinatorial optimization problems that has many applications in the industrial field (Geetha, 2016). VRP has several main types of problems namely Capacitated Vehicle Routing Problems (CVRP), Vehicle Routing Problems with Pick Up and Delivery (VRPPD), Distance Constrained Vehicle Routing Problems (DCVRP), Vehicle Routing Problems with Multiple Depots (VRVP) VRPMD), Split Delivery Vehicle Routing Problem (SDVRP), and Vehicle Routing Problem with Time Windows (VRPTW) (Toth and Vigo, 2002). In this case the customer's request is limited by the amount of load possessed by the capacity of the Tanker, so the Capacitated Vehicle Routing Problem (CVRP) is used which is an optimization problem to determine the route with minimal cost.

Boyolali Fuel Terminal has 14 areas covered as a distribution network which the total number of fuel stations as of December 2018 is 238 stations. Meanwhile, the total demand is around 8168 kiloliters per month. The Demand per Area shown in Table 2 below.

Table 2. Demand per Area for Boyolali Fuel Terminal

Area	Quantity	Average Demand in Kl (Jan-Nov 2018)
Sourthen Semarang	14	527
Salatiga	18	627
Surakarta	25	629
Sragen	26	627
Boyolali	17	668
Klaten	24	649
Sukoharjo	20	721
Wonogiri	14	781
Karanganyar	21	677
Purwodadi	14	695
Blora	3	652
Ngawi	17	207
Magetan	16	272
Pacitan	9	436

In meeting the demand at 238 fuel stations that are spread out, TBBM has a large fuel tank fleet of 103 trucks originating from outsourcing. The trucks are not only available in one capacity, but three. The trucks are available in capacities of 16, 24 and 32 kiloliters. The Capacity of Truck shown in Table 3 below.

Table 3. The Capacity of Total Truck

	Capacity	Quantity
Truck A	16	29
Truck B	24	53
Truck C	32	21

In this study, the distribution of fuel from Boyolali TBBM will only be seen in distribution to the Boyolali gas station. The total number of Boyolali gas stations was 16 coded 44,573.01 to 44,573.16. The distance from TBBM and each gas station can be seen in the Table 4. Demand for each gas station can also be seen in the picture. In this study, the demand is assumed that for one month there will be 80 shipments to each gas station.

Table 4. Distance Between Each Gas Stations and its Demand

From/To (km)	TBBM	44.573.01	44.573.02	44.573.03	44.573.04	44.573.05	44.573.06	44.573.07	44.573.08	44.573.09	44.573.10	44.573.11	44.573.12	44.573.13	44.573.14	44.573.15	44.573.16
TBBM	0	30	9.1	21	5.8	14	31	13	16	14	13	7.6	18	12	34	9.4	8.3
44.573.01	30	0	34	33	44	39	14	17	51	36	46	45	33	46	17	33	42
44.573.02	9.1	34	0	6.9	22	20	32	26	33	13	22	21	9.1	22	22	19	17
44.573.03	21	33	6.9	0	20	11	20	21	21	7.6	17	16	4.1	17	22	14	14
44.573.04	5.8	44	22	20	0	9.3	31	22	13	8.3	11	5.3	16	11	37	8.3	6.2
44.573.05	14	39	20	11	9.3	0	25	18	17	3.2	6.2	5.9	6.9	6	27	4.2	3.2
44.573.06	31	14	32	20	31	25	0	18	43	22	32	31	19	31	3.1	28	28
44.573.07	13	17	26	21	22	18	18	0	28	17	22	21	19	22	21	13	18
44.573.08	16	51	33	21	13	17	43	28	0	20	19	12	24	17	44	18	14
44.573.09	14	36	13	7.6	8.3	3.2	22	17	20	0	9.4	9.1	3.7	9.2	24	5.7	6.3
44.573.10	13	46	22	17	11	6.2	32	22	19	9.4	0	7.2	14	10	34	9.1	5.3
44.573.11	7.6	45	21	16	5.3	5.9	31	21	12	9.1	7.2	0	12	6	33	7.3	2.6
44.573.12	18	33	9.1	4.1	16	6.9	19	19	24	3.7	14	12	0	9.2	21	9.3	10
44.573.13	12	46	22	17	11	6	31	22	17	9.2	10	6	9.2	0	34	9.2	4.5
44.573.14	34	17	22	22	37	27	3.1	21	44	24	34	33	21	34	0	30	31
44.573.15	9.4	33	19	14	8.3	4.2	28	13	18	5.7	9.1	7.3	9.3	9.2	30	0	5
44.573.16	8.3	42	17	14	6.2	3.2	28	18	14	6.3	5.3	2.6	10	4.5	31	5	0
Demand	0	15	10	11	7	7	12	7	6	10	6	7	11	12	5	7	4

In addition, the number of trucks operating that deliver fuel to the Boyolali gas station is assumed to be 12. The truck consists of two variations of capacity, 16 kiloliters and 32 kiloliters. Trucks with a capacity of 16 kiloliters totaled 10 units while trucks with a capacity of 32 kiloliters totaled 2 units.

3. Results and discussion

Data processing is done using OR-Tools software. OR-Tools is an open source optimization software developed by Google AI, created to solve the world's toughest problems in vehicle routing, flow, integer and linear programming, and obstacle programming (Google, 2020). After modeling the problem in the user's choice programming language, the user can use one of many problem-solving examples to solve: commercial problem solving such as Gurobi or CPLEX, or solving open-source problems such as SCIP, GLPK, or Google GLOP and CP award-winning problems –SAT.

In this paper, there are two stages. The first stage is the process of making programming logic in Python using the Google OR-Tools algorithm. The second stage is the process of running data to finally get the optimal number of routes. The first step is to enter the distance data between nodes, namely the distance between Boyolali TBBM to each gas station in Boyolali and the distance between each gas station in Boyolali itself. This distance data is entered into a matrix format as shown in Figure 1. After entering distance data, the next step is to enter demand data per gas station, the number of vehicles and the capacity of each vehicle. They are shown in Figure 2. The last step is to run python software. At this stage python will do several iterations. The trial uses the heuristic method, where this method will find the optimal solution by looking directly for the value obtained in each iteration. The results of the running are as follows illustrated in Figure 3.

```
def create_data_model():
    """Stores the data for the problem."""
    data = {}
    data['distance_matrix'] = [
        [0, 30, 9.1, 21, 5.8, 14, 31, 13, 16, 14, 13, 7.6, 18, 12, 34, 9.4, 8.3],
        [30, 0, 34, 33, 44, 39, 14, 17, 51, 36, 46, 45, 33, 46, 17, 33, 42],
        [9.1, 34, 0, 6.9, 22, 20, 32, 26, 33, 13, 22, 21, 9.1, 22, 22, 19, 17],
        [21, 33, 6.9, 0, 20, 11, 20, 21, 21, 7.6, 17, 16, 4.1, 17, 22, 14, 14],
        [5.8, 44, 22, 20, 0, 9.3, 31, 22, 13, 8.3, 11, 5.3, 16, 11, 37, 8.3, 6.2],
        [14, 39, 20, 11, 9.3, 0, 25, 18, 17, 3.2, 6.2, 5.9, 6.9, 6, 27, 4.2, 3.2],
        [31, 14, 32, 20, 31, 25, 0, 18, 43, 22, 32, 31, 19, 31, 3.1, 28, 28],
        [13, 17, 26, 21, 22, 18, 18, 0, 28, 17, 22, 21, 19, 22, 21, 13, 18],
        [16, 51, 33, 21, 13, 17, 43, 28, 0, 20, 19, 12, 24, 17, 44, 18, 14],
        [14, 36, 13, 7.6, 8.3, 3.2, 22, 17, 20, 0, 9.4, 9.1, 3.7, 9.2, 24, 5.7, 6.3],
        [13, 46, 22, 17, 11, 6.2, 32, 22, 19, 9.4, 0, 7.2, 14, 10, 34, 9.1, 5.3],
        [7.6, 45, 21, 16, 5.3, 5.9, 31, 21, 12, 9.1, 7.2, 0, 12, 6, 33, 7.3, 2.6],
        [18, 33, 9.1, 4.1, 16, 6.9, 19, 19, 24, 3.7, 14, 12, 0, 9.2, 21, 9.3, 10],
        [12, 46, 22, 17, 11, 6, 31, 22, 17, 9.2, 10, 6, 9.2, 0, 34, 9.2, 4.5],
        [34, 17, 22, 22, 37, 27, 3.1, 21, 44, 24, 34, 33, 21, 34, 0, 30, 31],
        [9.4, 33, 19, 14, 8.3, 4.2, 28, 13, 18, 5.7, 9.1, 7.3, 9.3, 9.2, 30, 0, 5],
        [8.3, 42, 17, 14, 6.2, 3.2, 28, 18, 14, 6.3, 5.3, 2.6, 10, 4.5, 31, 5, 0],
    ]
```

Figure 1. Data Distance Matrix Input on Python

```
data['demands'] = [0, 15, 10, 11, 7, 7, 12, 7, 6, 10, 6, 7, 11, 12, 5, 7, 4]
data['vehicle_capacities'] = [16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 32, 32]
data['num_vehicles'] = 12
data['depot'] = 0
return data
```

Figure 2. Data Demand, Vehicle Capacities and Number Matrix Input on Python

```
Route for vehicle 0:
 0 Load(0) ->  0 Load(0)
Distance of the route: 0m
Load of the route: 0

Route for vehicle 1:
 0 Load(0) ->  0 Load(0)
Distance of the route: 0m
Load of the route: 0

Route for vehicle 2:
 0 Load(0) ->  0 Load(0)
Distance of the route: 0m
Load of the route: 0

Route for vehicle 3:
 0 Load(0) ->  0 Load(0)
Distance of the route: 0m
Load of the route: 0

Route for vehicle 4:
 0 Load(0) ->  13 Load(12) ->  16 Load(16) ->  0 Load(16)
Distance of the route: 24m
Load of the route: 16

Route for vehicle 5:
 0 Load(0) ->  1 Load(15) ->  0 Load(15)
Distance of the route: 60m
Load of the route: 15

Route for vehicle 6:
 0 Load(0) ->  4 Load(7) ->  0 Load(7)
Distance of the route: 10m
Load of the route: 7

Route for vehicle 7:
 0 Load(0) ->  6 Load(12) ->  0 Load(12)
Distance of the route: 62m
Load of the route: 12

Route for vehicle 8:
 0 Load(0) ->  7 Load(7) ->  14 Load(12) ->  0 Load(12)
Distance of the route: 68m
Load of the route: 12

Route for vehicle 9:
 0 Load(0) ->  8 Load(6) ->  11 Load(13) ->  0 Load(13)
Distance of the route: 35m
Load of the route: 13

Route for vehicle 10:
 0 Load(0) ->  2 Load(10) ->  3 Load(21) ->  12 Load(32) ->  0 Load(32)
Distance of the route: 37m
Load of the route: 32

Route for vehicle 11:
 0 Load(0) ->  10 Load(6) ->  5 Load(13) ->  9 Load(23) ->  15 Load(30) ->  0 Load(30)
Distance of the route: 36m
Load of the route: 30

Total distance of all routes: 332m
Total load of all routes: 137
```

Figure 3. Route for Each Vehicle on Python

From the results of simulation by Python, several routes are generated. Of the total 12 trucks there are 8 trucks operating and there are 4 trucks that are not operating. Trucks number 1, 2, 3 and 4 with a total capacity of 16 kiloliters do not deliver. Figure 4 illustrates the solution for the fuel distribution route.

The route for truck number 5 with a total capacity of 16 kiloliters is to deliver gas stations 44.573.13 for 12 kiloliters and to 44.573.16 for 4 kiloliters. The total distance traveled by this route is 24 km and the total fuel transported is 16 kiloliters. The route for truck number 6 with a total capacity of 16 kiloliters is only to deliver to gas station 44.573.01 for 15 kiloliters. The total distance traveled by this route is 60 km and the total fuel transported is 15 kiloliters. The route for truck number 7 with a total capacity of 16 kiloliters is only delivering to gas stations 44.573.04 for 7 kiloliters. The total distance traveled by this route is 10 km and the total fuel transported is 7 kiloliters.

The route for truck number 8 with a total capacity of 16 kiloliters only delivers 44,573.06 gas stations as many as 12 kiloliters. The total distance traveled by this route is 62 km and the total fuel transported is 12 kiloliters. The route for truck number 9 with a total capacity of 16 kiloliters delivers 7 kiloliters of gas stations as many as 7 kiloliters and 5 kiloliters to 44.573.14. The total distance traveled by this route is 68 km and the total fuel transported is 12 kiloliters. The route for truck number 10 with a total capacity of 16 kiloliters is delivering to gas station 44.573.08 with 6 kiloliters and to 44.573.11 with 7 kiloliters. The total distance traveled by this route is 35 km and the total fuel transported is 13 kiloliters. The route for truck number 11 with a total capacity of 32 kiloliters is to deliver to gas station 44.573.02 for 10 kiloliters, to 44.573.03 for 11 kiloliters, to 44.573.12 for 11 kiloliters. The total distance traveled by this route is 37 km and the total fuel carried is 32 kiloliters. The route for truck number 12 with a total capacity of 32 kiloliters delivers 6 kiloliters to gas stations 44 kiloliters, to 44.573.05 as many as 7 kiloliters, to 44.573.09 as many as 10 kiloliters, and to 44.573.15 as many as 7 kiloliters. The total distance traveled by this route is 36 km and the total fuel transported is 30 kiloliters.

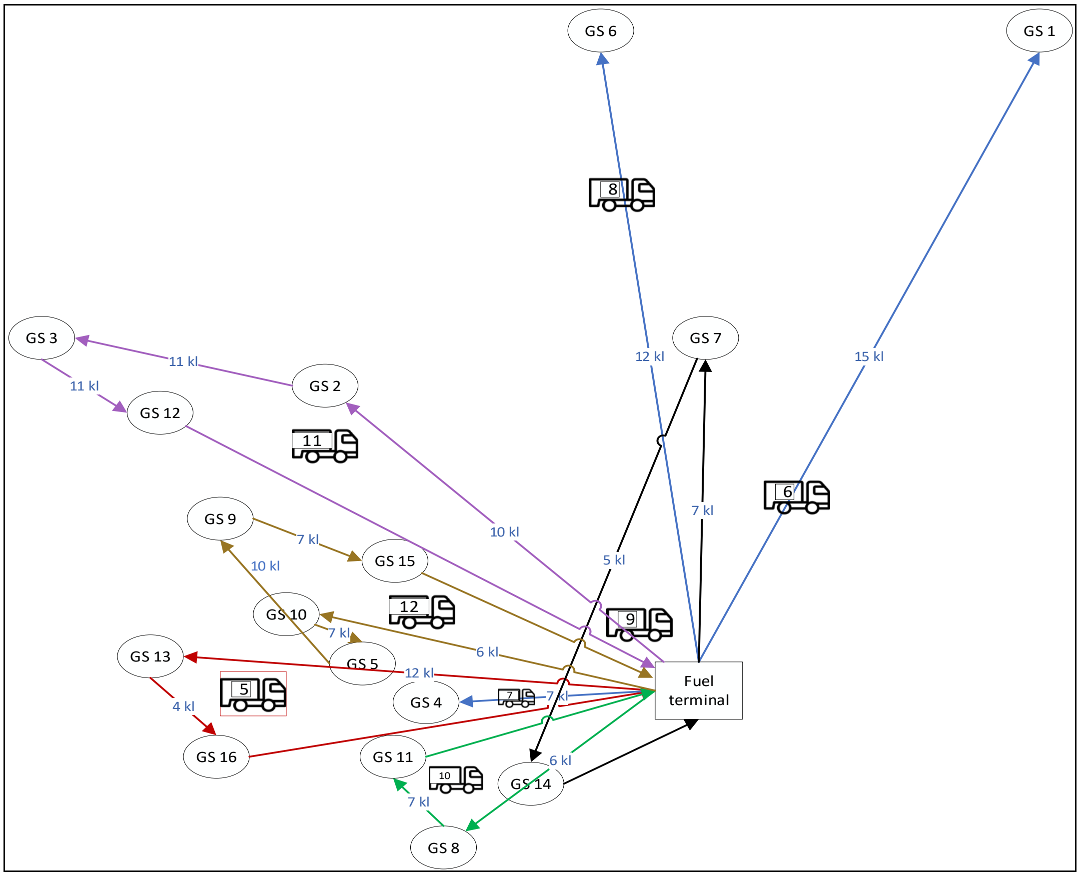

Figure 4. Fuel distribution route solution

The total distance traveled by trucks on all routes is 332 km, while the total fuel carried is 137 kiloliters. The total fuel has been able to meet all the demands that exist at each gas station in Boyolali. There are 4 trucks that are unemployed, these trucks can be allocated to gas stations outside Boyolali so that they can operate more effectively and efficiently.

4. Conclusion

The Boyolali Fuel Terminal is tasked with distributing fuel oil to refueling stations in several areas, such as South Semarang, Salatiga, Surakarta, Sragen, Boyolali, Sukoharjo Klaten, Wonogiri, Karanganyar, Purwodadi, Blora, Ngawi, Magetan and Pacitan. Boyolali Fuel Terminal distributes BBM to 238 gas stations. It has to optimize the distribution of fuel to gas stations to achieve operational excellence. In this study suggest Boyolali Fuel Terminal to use only 8 trucks to distribute fuel in Boyolali area. Another trucks can be rellocated to another area. This article has certain limitation that should be overcome in order to provide in deep analysis on the vehicle distribution analysis. For further research will complete the research with additional constraints such as time windows, pickup and deliveries, dimensions and resource constraints to increase the closeness of the solution to the real system.

References

Battara, M., Edorgan, G., and Vigo, D., Exact Algorithms for the Clustered Vehicle Routing Problem, *Operations Research*, vol. 62, no. 1, pp. 58-71, 2014.

Benantar, A., and Ouafi, R., Optimization Of Vehicle Routes: An Application To Logistic And Transport Of The Fuel Distribution, *9th International Conference on Modeling, Optimization & SIMulation,* Bordeaux, France, June 6-8, 2012.

Bruniecki, K., Chybicki, A., Moszynski, M., & Bonecki, M., Evaluation of vehicle routing problem algorithms for transport logistics using dedicated GIS system, *Baltic Geodetic Congress (BGC Geomatics),* Gdansk, Poland, June 2-4, 2016, pp. 116-121, 2016.
Cetin, S., A heuristic algorithm for vehicle routing problems with simultaneous pick-up and delivery and hard time windows, *Open Journal of Social Sciences*, vol. 3, no. 03, p. 35, 2015.
Expósito-Izquierdo, C., Rossi, A., and Sevaux, M., A two-level solution approach to solve the clustered capacitated vehicle routing problem, *Computers & Industrial Engineering*, vol. 91, pp. 274-289, 2016.
Geetha, S., Poonthalir, G., and Vanathi, P., Metaheuristic approach for the multi-depot vehicle routing problem, *Applied Artificial Intelligence,* vol. 26, no. 9, pp. 878-901, 2012.
Google, About OR-Tools, Available: https://developers.google.com/optimization/introduction/overview, May 21, 2020.
Henke, T., Speranza, M. G., and Wäscher, G., The multi-compartment vehicle routing problem with flexible compartment sizes, *European Journal of Operational Research*, vol. 246, no. 3, pp. 730-743, 2015.
Marc, A. H., Fuksz, L., Pop, P. C., and Dănciulescu, D., A novel hybrid algorithm for solving the clustered vehicle routing problem, *International Conference on Hybrid Artificial Intelligence Systems*, pp. 679-689, 2015.
Reed, M., Yiannakou, A., and Evering, R., An ant colony algorithm for the multi-compartment vehicle routing problem, *Applied Soft Computing*, vol. 15, pp. 169-176, 2014.
Sharma, S. K., Routroy, S., and Yadav, U., Vehicle routing problem: recent literature review of its variants, *International Journal of Operational Research*, vol. 33, no. 1, pp. 1-31, 2018.
Skok, M., Skrlec, D., and Krajcar, S., The genetic algorithm method for multiple depot capacitated vehicle routing problem solving, *KES'2000. Fourth International Conference on Knowledge-Based Intelligent Engineering Systems and Allied Technologies. Proceedings (Cat. No.00TH8516),* Brighton, UK, 30 Aug.-1 Sept. 2000, vol. 2, pp. 520-526, 2000.
Surjandari, I., Rachman, A., Dianawati, F., and Wibowo, R. P., Petrol delivery assignment with multi-product, multi-depot, split deliveries and time windows, *International Journal of Modeling and Optimization*, vol. 1, no. 5, p. 375, 2011.
Vidal, T., Battarra, M., Subramanian, A., and Erdogˇan, G., Hybrid metaheuristics for the clustered vehicle routing problem, *Computers & Operations Research*, vol. 58, pp. 87-99, 2015.
Yahyaoui, H., Kaabachi, I., Krichen, S., and Dekdouk, A., Two metaheuristic approaches for solving the multi-compartment vehicle routing problem, *Operational Research*, pp. 1-24, 2018.

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