PAPER • OPEN ACCESS

A study of vehicle routing problem via trade-off ranking method

To cite this article: Nor Izzati Jaini *et al* 2021 *J. Phys.: Conf. Ser.* **1988** 012053

A study of vehicle routing problem via trade-off ranking method

Nor Izzati Jaini[1], Adam Shariff Adli Aminuddin[2], Farahanim Misni[3] and Zaitul Marlizawati Zainuddin[4]

[1,2,3] Center for Mathematical Sciences, College of Computing & Applied Sciences, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Pahang, Malaysia
[4] Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

Email: [1]ati@ump.edu.my, [2]adamshariff@gmail.com, [3]farahanim@ump.edu.my, [4]zmarlizawati@utm.my

Abstract. Vehicle routing defines selecting the minimum cost, distance, and/or time path from a depot to several alternatives for a goods or service to reach its destination. The objective of most routing problem is to minimize the total cost of providing the service. But other objectives also may come into play, particularly in the public sector. For emergency services, such as ambulance, police, and fire engine, minimizing the response time to an incident is of primary importance. A few routing algorithms do not use a deterministic algorithm to find the "best" route for a goods to get from its original source to its destination. Instead, to avoid congestion, a few algorithms use a randomized algorithm that routes a path to a randomly picked intermediate destination, and from there to its true destination. In this paper, the trade-off ranking method is used to solve for the vehicle routing treated as a conflicting multi-criteria problem. The integration of the trade-off ranking method into the vehicle routing problem gives another perspective on how to solve the problem, hence broadened the decision support system for the vehicle routing problem.

1. Introduction

The first model of vehicle routing problem (VRP) was solved by Dantzig and Ramser [1]. They develop a mathematical programming to solve gas delivery to service stations. From then, the VRP evolved and extensively studied. The VRP is considered as NP-hard problem. Thus, the problem is usually solved using heuristics or meta-heuristics algorithm. Using such algorithm, the optimal solution is not guaranteed, however it is the best method to solve the VRP in real-life problem, due to their high-performance. The real-life problem usually involves several criteria which are conflicting between each other. The most common objective of VRP is to minimize the total distance of vehicle routes. However, for delivery service, maximize the fulfillment of the customers' demand may be the one of the objective. But then, to minimize the total distance travel by a vehicle while maximizing the demand of the customer can be conflicting, moreover during peak hours. The Decision Maker (DM), where in the delivery service would be the rider, may have to choose between the two conflicting objective. In making a decision, there is no right or wrong. As making decision **A** may be the best for one, taking **B** would be the best for others.

Hence the main contribution of this paper is a study of VRP via trade-off ranking method, which is a method used to solve multi-criteria decision making problem with conflicting criteria [2]. The method aims to give the best solution that reflects the DM's preference and minimize the trade-off between the conflicting criteria.

The rest of the paper is organized as follows. The literature on types of VRP and methods used to solve the problem is presented in section 2. The trade-off ranking method is briefly discussed in section 3. In section 4, the test case for VRP is solved via trade-off ranking method. Lastly, the conclusion is given in section 5.

2. Vehicle routing problem and solution methods

Many methods have been used to solve abundance VRP problems. Jeon et al. [3] considered a hybrid genetic algorithm solving a VRP problem with heterogeneous vehicles, double trips, and multiple depots. Akbar and Aurachmana [4] considered a problem of capacitated vehicle routing problem with time windows (CVRPTW), with pick-up and delivery for mineral water company distributor. They used a hybrid genetic-tabu search algorithm to solve the CVRPTW. Pan et al. [5] also considered a capacitated vehicle routing problem (CVRP). They implemented the multi-group grasshopper optimisation algorithm (MGOA), which is an algorithm mimicking the behaviour of grasshopper in nature. Carić and Fosin [6] used historical data to solve the time dependent vehicle routing problem (TDVRP). They derived a zone of congestion during certain times and applied it to an optimisation algorithm to find the solution. Ng et al. [7] solved the CVRP using artificial colony algorithm with multiple colonies. They suggested the re-routing strategy to enhance the routing flexibility. Wang et al. [8] addressed a two-echelon capacitated routing problem (2E-CVRP). They designed a metaheuristic method based on variable neighbourhood search and integer programming to solve the 2E-CVRP. Wei et al. [9] used simulated annealing algorithm to solve the capacitated vehicle routing problem with two-dimensional loading constraints (2L-CVRP). Santos et al. [10] proposed a branch-cut-and-price algorithm. They suggested the use of intermediate depots called satellite to solve 2E-CVRP [10].

Sitek et al. [11] considered the CVRP with alternative delivery, pick-up, and time windows. They solved the problem using a hybrid of Constraint Programming, Genetic Algorithm and Mathematical Programming. Zhen et al. [12] used hybrid particle swarm optimization and hybrid genetic algorithm to solve the problem of designing a set of tris for the fleet of vehicles supplied by different depots. Zulvia e al. [13] proposed green VRP considering time windows, working hours, and different travelling time. The proposed model is solved using a many-objective gradient evolution (MOGE). Zhang et al. [14] presented a novel model of fuzzy electric vehicle routing problem with time windows and recharging stations (FEVRPTW). They used fuzzy numbers to denote the uncertainties in the model parameter. The model is solved using an adaptive large neighbourhood search (ALNS) algorithm.

Many other methods have been widely used in solving variants of VRP model. In this paper, we are using the trade-off ranking method [2] to solve the capacitated VRP with conflicting criteria. In a capacitated VRP model, the vehicle has limited capacity, thus it can only reach to a certain place, and not all. Consider a model of n customers, in which due to some restrictions, the vehicle can only approach some of the customers. Thus, choosing a set of customers to be served may depends on the objective of the travelling. Moreover, with the pandemic crisis, travelling is limited to a certain place and for a certain reason only. With the current pandemic as the motivation, we are looking to solve the VRP as a conflicting multi-criteria problem, where the objectives of the travelling are treated as criteria and the customers are regarded as the alternatives. Now, given a set of j alternatives (customers), the DM (traveller) must choose which alternative is the best to fulfil the i criteria (objectives). In the next subsection, we briefly discussed the trade-off ranking algorithm, used to solve the conflicting criteria VRP.

3. Trade-off ranking method algorithm

The trade-off ranking method has been used to solve various multi-criteria decision-making problems, moreover in a conflicting environment, including a general test cases, a car selection problem [2], and a personnel selection problem [15]. The algorithm of the trade-off ranking method used to solve the VRP is given as follows: [15]

1. Normalize the criteria value, Y_{ij} (distance, demand, profit, etc.) using the formula:

$$f_{ij} = \frac{Y_{ij} - \min_j Y_{ij}}{\max_j Y_{ij} - \min_j Y_{ij}}, i = 1,...,q, \ j = 1,...,n. \quad (1)$$

where f_{ij} is the value of each criteria *i* and alternative *j* after normalization.

2. Determine the objective of each criteria (max or min).
3. Determine the extreme solutions, A_k^* using the formula:

$$A_k^* = \begin{cases} \min\limits_{1 \le i \le q} f_{ij}, \ j = 1,...,n \text{ for the cost criteria} \\ \max\limits_{1 \le i \le q} f_{ij}, \ j = 1,...,n \text{ for the benefit criteria} \end{cases} \quad (2)$$

4. Calculate the differences of each criteria for every customer, A_α and the extreme solutions, A_k^* using the distance formula as:

$$d\left(A_k^*, A_\alpha\right) = \left[\sum_{j=1}^{n} \left(f_{kj}, f_{\alpha j}\right)^2\right]^{1/2}. \quad (3)$$

5. Calculate the trade-off between each customer by formula:

$$DT_{A_\alpha} = \sum_{j=1}^{n} \left[w_j \times d\left(A_k^*, A_\alpha\right)\right], \alpha = 1,...,q, k = 1,...,n. \quad (4)$$

where w_j is the weight for criteria *j*.

6. Rank the customer accordingly. Customer with the least trade-off value, DT_{A_α} is ranked at the top.

In the next subsection, a test case is solved using the trade-off ranking algorithm.

4. Experimental study

Consider a VRP with single depot, 1 vehicle and 18 customers. The data for the location of each customer (given as latitude and longitude), distance from the depot (in km), demand per customer and profit (RM) are shown as table 1.

Table 1. Information about the customers to be served.

Customer	Latitude	Longitude	Distance (km)	Demand	Profit (RM)
Depot	35.7203120	-5.9206340	0	0	0
C1	35.739811	-5.839599	9.2	1	25
C2	35.735212	-5.879596	8.39	6	150
C3	35.738626	-5.873669	6.74	1	25
C4	35.754001	-5.824116	11.25	3	75
C5	35.753916	-5.809254	14	3	75
C6	35.7591954	-5.847911	9.72	1	25
C7	35.7359144	-5.9258994	5.4	3	75
C8	35.750991	-5.82757	10.51	1	25
C9	35.765434	-5.832548	11.11	1	25
C10	35.751059	-5.8627424	8.32	1	25
C11	35.7656173	-5.8675222	11.15	1	25
C12	35.7820953	-5.842395	14.34	1	25
C13	35.7538851	-5.8350188	10.16	1	25
C14	35.7595297	-5.8690597	9.67	1	25

C15	35.7865563	-5.8657091	13.88	1	25
C16	35.776366	-5.8218403	14.25	1	25
C17	35.765502	-5.823849	12.27	1	25
C18	35.7647026	-5.8662061	10.68	1	25

As can be seen from table 1, the data for profit reflected the value of customers' demand. Thus, in the dataset provided, we only consider the distance travelled by the vehicle and the profit gained. The latitude and longitude are used for mapping purpose, as shown in figures 1-3.

The distance and profit criteria are conflicting criteria. The most profitable customer is C2 with RM150 profit. However, it is not the closest to the depot. The closest one would be C7 with distance value of 5.4km and gives RM75 of profit, half-less than C2. Note that, the distance is the cost criteria, which we want to minimize, while the profit is the benefit criteria to be maximized.

Let say, in certain times, the DM can only travel to half of the customers. Thus, looking roughly at the data, one DM may choose to travel to C7 first if the DM's aims is to minimize the distance. On the other hand, other DM may want to travel to C2 to gain as much profit as possible, regardless the distance.

By implementing the trade-off ranking algorithm to the problem via equations (1)-(4), table 3 shows the result of the ranking. In this case, we investigate a problem of constraint resources where the DM can only cater 10 customers to be served at one time. The VRP is considered in three objectives; (i) to minimize distance, (ii) to maximize profit; (iii) trade-off in between distance and profit.

In objective (i), we set the weightage for distance criteria as 1, and profit criteria as 0. Meanwhile for objective (ii), it is vice-versa. In objective (iii), both criteria are considered equally important, hence the weights are set to 0.5 each.

Since the data in table 1 gives the distance of each customer from the depot only, the distances in between customers are approximated using the Pythagoras formula. In the case of uncertainty, approximation is considered adequate as a reliable information.

Table 2. VRP route for the three objectives

Objective	Route	Approximated distance travelled (km)	Profit (RM)
i	Depot-C3-C10-C7-C1-C14-C6-C13-C8-C18-C9	16.95	300
ii	Depot-C2-C4-C7-C5-C10-C1-C14-C6-C3-C13	36.19	525
iii	Depot-C2-C7-C3-C10-C4-C1-C14-C6-C13-C8	17.60	475

From table 2, the trade-off ranking method proposes a route for objective (i) with minimum approximate total distance at 16.95km. For objective (ii), since the goal is to maximize profit, then the trade-off ranking method proposes a solution with total profit of RM525, regardless of distance, where in this objective, it took the longest distance to travel. In a win-win situation, i.e., minimize the distance travel while maximize the profit, the trade-off ranking method gives a route solution with least compromise of both criteria. Figures 1-3 show the route taken for each objective.

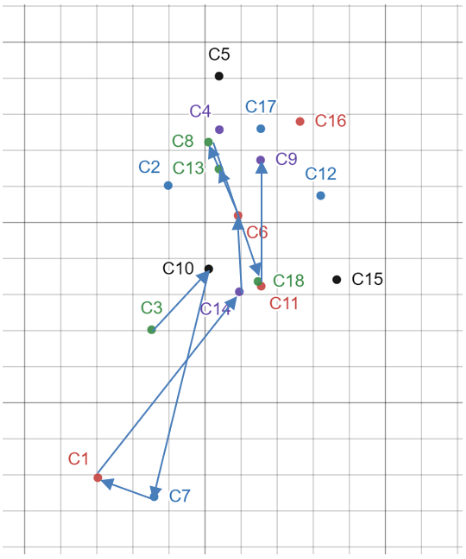

Figure 1. Proposed route for objective (i)

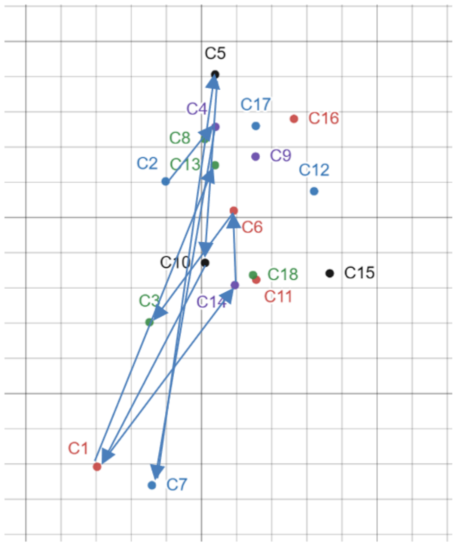

Figure 2. Proposed route for objective (ii)

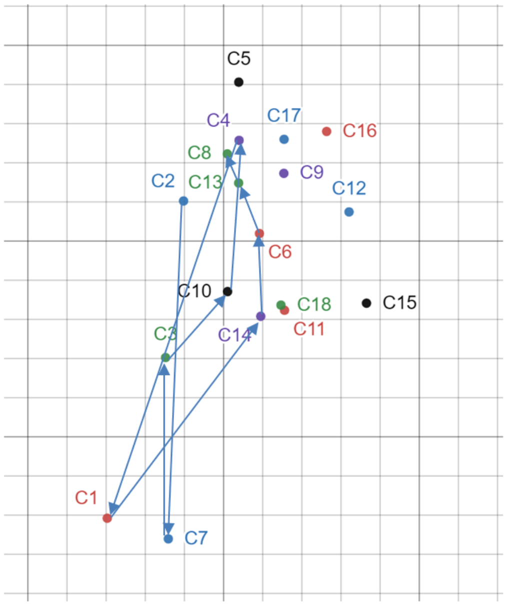

Figure 3. Proposed route for objective (iii)

5. Conclusion

In this paper, a trade-off ranking method has been used to solve the capacitated VRP by treating the problem as a conflicting multi-criteria problem. In such a problem, the solution is not unique. It depends on the DM's preference towards one or more criteria. From the experimental objective, the trade-off ranking method proposes a route with least compromise value in between the distance and the profit. Further research of testing the trade-off ranking method with VRP would be done in the future considering other variants of VRP, including with time windows, multi-depots, and multi-vehicles.

Acknowledgement

The authors would like to thank the Ministry of Higher Education for providing financial support under Fundamental Research Grant No. FRGS/1/2018/STG06/UMP/02/10 (University reference RDU190198). We also would like to thank the reviewers for their comments and suggestions to further improve the paper.

References

[1] Dantzig GB, Ramser JH. The truck dispatching problem. Management science. 1959 Oct;6(1):80-91.

[2] Jaini N, Utyuzhnikov S. Trade-off ranking method for multi-criteria decision analysis. Journal of Multi-Criteria Decision Analysis. 2017 May;24(3-4):121-32.

[3] Jeon G, Leep HR, Shim JY. A vehicle routing problem solved by using a hybrid genetic algorithm. Computers & Industrial Engineering. 2007 Nov 1;53(4):680-92.

[4] Akbar MD, Aurachmana R. Hybrid genetic–tabu search algorithm to optimize the route for capacitated vehicle routing problem with time window. Int. J. Ind. Optim. 2020 Feb 29;1:15-28.

[5] Pan JS, Wang X, Chu SC, Nguyen TT. A multi-group grasshopper optimisation algorithm for application in capacitated vehicle routing problem. Data Science and Pattern Recognition. 2020;4(1):41-56.

[6] Carić T, Fosin J. Using congestion zones for solving the time dependent vehicle routing problem. Promet-Traffic&Transportation. 2020 Jan 27;32(1):25-38.

[7] Ng KK, Lee CK, Zhang SZ, Wu K, Ho W. A multiple colonies artificial bee colony algorithm for a capacitated vehicle routing problem and re-routing strategies under time-dependent traffic congestion. Computers & Industrial Engineering. 2017 Jul 1;109:151-68.

[8] Wang K, Shao Y, Zhou W. Matheuristic for a two-echelon capacitated vehicle routing problem with environmental considerations in city logistics service. Transportation Research Part D: Transport and Environment. 2017 Dec 1;57:262-76.

[9] Wei L, Zhang Z, Zhang D, Leung SC. A simulated annealing algorithm for the capacitated vehicle routing problem with two-dimensional loading constraints. European Journal of Operational Research. 2018 Mar 16;265(3):843-59.

[10] Santos FA, Mateus GR, da Cunha AS. A branch-and-cut-and-price algorithm for the two-echelon capacitated vehicle routing problem. Transportation Science. 2015 May;49(2):355-68.

[11] Sitek P, Wikarek J, Rutczyńska-Wdowiak K, Bocewicz G, Banaszak Z. Optimization of capacitated vehicle routing problem with alternative delivery, pick-up and time windows: A modified hybrid approach. Neurocomputing. 2021 Jan 29;423:670-8.

[12] Zhen L, Ma C, Wang K, Xiao L, Zhang W. Multi-depot multi-trip vehicle routing problem with time windows and release dates. Transportation Research Part E: Logistics and Transportation Review. 2020 Mar 1;135:101866.

[13] Zulvia FE, Kuo RJ, Nugroho DY. A many-objective gradient evolution algorithm for solving a green vehicle routing problem with time windows and time dependency for perishable products. Journal of Cleaner Production. 2020 Jan 1;242:118428.

[14] Zhang S, Chen M, Zhang W, Zhuang X. Fuzzy optimization model for electric vehicle routing problem with time windows and recharging stations. Expert Systems with Applications. 2020 May 1;145:113123.

[15] Jaini NI, Utyuzhnikov SV. A fuzzy trade-off ranking method for multi-criteria decision-making. Axioms. 2018 Mar;7(1):1.