COMPARING DIFFERENT METAHEURISTIC METHODS IN SOLVING A REAL-WORLD APPLICATION OF VEHICLE ROUTING PROBLEM

W. Madushan Fernando, Amila Thibbotuwawa, H. Niles Perera
Center for Supply Chain, Operations and Logistics Optimization, University of Moratuwa, Katubedda 10400, Sri Lanka
madushanfernando69@gmail.com, amilat.uom@gmail.com, hniles@uom.lk

ABSTRACT – This research applied an extension of the Vehicle Routing Problem (VRP) to optimize the distribution processes of a supermarket chain. This model is a combination of CVRP (Capacitated VRP), MDVRP (Multi-depot VRP), and HFVRP (Heterogenous fleet VRP). The applied model aims to minimize the distribution cost of the selected supermarket chain. All the constraints of the VRP model were defined based on the operational practices of the application. The research aimed to compare the performances of three metaheuristic methods, Simulated Annealing (SA), Tabu Search (TS), and Guided Local Search (GLS) in optimizing the real-world application. Results highlighted that GLS outperformed in terms of the quality of the solutions and the computation time in optimizing the selected distribution network. This research is significant because it tests both the VRP model and the three metaheuristic methods using a real-world industry application.

Keywords: vehicle routing; real-world application; metaheuristic methods; supermarket chain

1. INTRODUCTION

Vehicle Routing Problem (VRP) is a well-studied application in the field of Operations Research [1]. The VRP was first introduced by Dantzig and Ramser (1959) as a "truck dispatching problem" [2]. The model attempted to find optimal routes from the central depot to gas stations for a homogeneous fleet of trucks [2]. VRP was later generalized as a linear optimization problem [3]. VRP is represented mathematically as a directed graph G (V, A), where V = {0, 1, 2, n} set of nodes and A = {(i, j):i,j ∈ N} indicates a set of arcs connecting nodes [3]. The depot is represented by node i=0, and other nodes indicate the customer locations. The fundamental version of VRP attempts to find the most economical route plan [3]. Various extensions of VRP have been published, such as capacitated VRP (CVRP), heterogenous fleet VRP (HFVRP), VRP with time windows (VRPTW), multi-depot VRP (MDVRP), multi-compartment VRP (MCVRP), VRP with pickup & deliveries (VRPPD), multi-echelon VRP (ME-VRP), and close-open mixed VRP (COMVRP), etc. [1].

Existing literature employed different solution approaches to solve the various types of route optimization problems [1]. Metaheuristic methods and exact methods are two types of solution approaches applied in the existing literature [1]. In the exact methods, search algorithms have been developed to examine the entire solution space to find the global optimal. Therefore, exact methods are not appropriate for the real-world applications of VRP, except the size of the problem is considerably small since exact methods take unrealistic computation time to solve complex problems. Generally, metaheuristic approaches do not examine the entire solution space. Therefore, metaheuristic approaches are unlike the exact methods and do not always promise global optimal solutions. However, those approaches can reach near-optimal solutions within a reasonable computation time. With the advancement in computation power, researchers found effective metaheuristic methods to tackle many VRP extensions [1]. Reference [1] highlights the research gap in comparing different metaheuristic approaches in solving real-world applications of VRP. Moreover, majority of VRP research is aimed at pure investigation and not at applications [1]. In consideration of above research gaps this research attempted to compare the performances of three well-known metaheuristic methods in solving an industry application of VRP.

2. METHODOLOGY

Figure 1 highlights the flowchart of task sequencing the three main steps in the proposed research design identified, developing the routing model, applying metaheuristic methods, and conducting the numerical experiments.

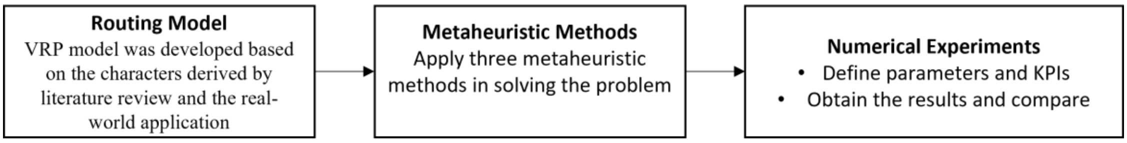

Figure 1. Research design

2.1. Routing Model

The VRP model applied in this research was inspired by reference [4]. However, the reference [4] used synthetic data to test the model, whereas the current study attempts to use real-world data. This VRP model is the combination of the following VRP extensions. Further, the routing model aims to find a route plan that minimizes the distribution cost.

- CVRP - Capacitated VRP applies to problems that are having vehicles with limited carrying capacity to pick up or deliver products [5].
- MDVRP - Multi-depot VRP is important when geographically dispersed multiple distribution centers serve customers [5].
- HFVRP – A fleet consists of vehicles with different capacities in real-world applications. Heterogenous fleet VRP tackles such applications [5].

2.2. Metaheuristic Methods

Simulated Annealing (SA), Tabu Search (TS), and Guided Local Search (GLS) were the selected metaheuristic methods to compare in this study. GLS is a memory-based method that uses an augmented cost function and a penalty [6]. To accept better solutions, SA employs a probabilistic approach and operates until it reaches near-optimality [6]. TS is a memory-based technique that examines neighboring solutions until the near-optimal is reached [6].

2.3. Numerical Experiments

The numerical experiments were performed on a computer with a Core i5, 5200U processor running at 2.40 GHz - 2.42 GHz, and 8 GB RAM running Windows 10 Home 64 bit. OR-Tools version 7.2 and Python version 3.9.6 in Visual studio code version 1.60 were used to create the algorithms. Data was collected from one of the largest supermarket chains operating in Sri Lanka to investigate the performances of the three metaheuristic methods in solving the selected VRP model. We collected data types including location data, demand data, fleet data, and operation data. OSRM (Open-Source Routing Machine) API was used to assess the distance matrix of the current research. Further, this research used distribution cost and the computation time as the KPIs to compare selected metaheuristic methods. The search process of metaheuristic methods continues until it violates the stopping criteria defined in the algorithm. This research employed a "number of accepted neighbors" as stopping criteria. Different metaheuristics use identical strategies to accept neighbors in an iterative process during the neighborhood search process.

3. RESULTS AND DISCUSSION

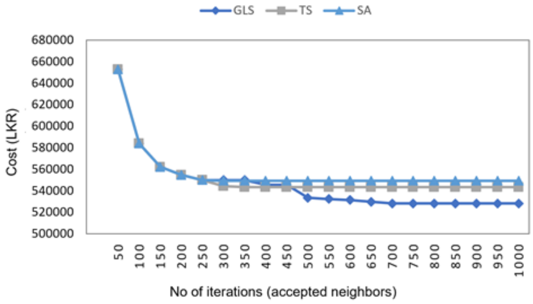

Figure 2. Distribution cost compariso

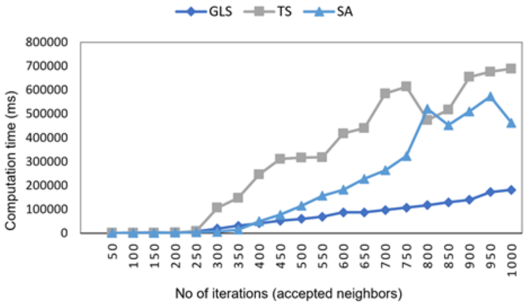

Figure 3. Computation time comparison

Iteration results obtained for the three metaheuristic methods are highlighted in Figure 2 and Figure 3. Figure 2 highlights the daily distribution cost of the selected supermarket chain resulting from the three metaheuristic methods. Results depict that GLS optimized the selected distribution network more than the other two metaheuristic methods. Figure 3 summarized the computation time of three metaheuristic methods. According to that, GLS reaches near-optimality in less computation time compared to the other two methods. Therefore, GLS outperformed in solving the selected real-world application of VRP.

4. CONCLUSION

This study attempts to fill a research gap by comparing different metaheuristic methods for solving real-world VRP applications. This research found that GLS outperformed in terms of the quality of the solutions and the computation time in solving the selected industry application. Moreover, numerical experiments revealed that using the VRP model and the GLS results in a 16 % cost savings in the daily distribution process of the selected application. This research can be extended by using several other industry applications to test the VRP model and the metaheuristic methods.

ACKNOWLEDGEMENT

This research was funded by the Senate Research Committee, the University of Moratuwa, Sri Lanka, through Grant ID SRC/LT/2020/20 and SRC/LT/2021/22.

REFERENCES

1. R. Moghdani, K. Salimifard, E. Demir, and A. Benyettou, “The green vehicle routing problem : A systematic literature review,” *J. Clean. Prod.*, vol. 279, p. 123691, 2021, doi: 10.1016/j.jclepro.2020.123691.
2. G. B. Dantzig and J. H. Ramser, “The Truck Dispatching Problem,” *Manage. Sci.*, vol. 6, no. 1, pp. 80–91, 1959, doi: 10.1287/mnsc.6.1.80.
3. G. Clarke and J. W. Wright, “Scheduling of Vehicles from a Central Depot to a Number of Delivery Points,” *Oper. Res.*, vol. 12, no. 4, pp. 568–581, 1964, doi: 10.1287/opre.12.4.568.
4. S. Salhi, A. Imran, and N. A. Wassan, “The multi-depot vehicle routing problem with heterogeneous vehicle fleet: Formulation and a variable neighborhood search implementation,” *Comput. Oper. Res.*, vol. 52, pp. 315–325, 2014, doi: 10.1016/j.cor.2013.05.011.
5. A. Thibbotuwawa, G. Bocewicz, P. Nielsen, and B. Zbigniew, “Planning deliveries with UAV routing under weather forecast and energy consumption constraints,” *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 820–825, 2019, doi: 10.1016/j.ifacol.2019.11.231.
6. M. Fernando, A. Thibbotuwawa, H. N. Perera, and R. M. C. Ratnayake, “Close-Open Mixed Vehicle Routing Optimization Model with Multiple Collecting Centers to Collect Farmers’ Perishable Produce,” *Int. Conf. Adv. Technol.*, pp. 1–8, 2022.

ISSN: 2513-2504

Awards

Award Category	Sponsored by	Authors	Research Title
Best Research in Transport Planning	Master Hellie's Engineering Consultants (Pvt) Ltd	Dineth D. Dhananjaya, T. Sivakumar	A Trip Purpose Inference Framework Using Spatial Clustering and Bayesian Probability
Best Research in Urban Transport	Highway and Transport Management Consultants (Pvt) Ltd	Madumita Dey, Prakash P.S., Chandan Mysore Chandrashekar, Bharath H. Aithal	Land-Use Change Dynamics and Automated Feature Extraction Using High-Resolutions Satellite Imagery
Best Research in Maritime and Logistics	South Asia Gateway Terminals (Pvt) Ltd	Amila Rukshan Manatunga, Buddhi A. Weerasinghe, H. Niles Perera, Phillip Kiessner	Identifying the Operational Process of a Ro-Ro Terminal Using System Dynamics Modelling
Best Research in Supply Chain	No	Nimni Pannila, Madushan Madhava Jayalath, Amila Thibbotuwawa	Challenges for Circular Economy Adoption in Sustainable Food Supply Chains
Best Research in Undergraduate Research	Resource Management Associates (Pvt) Ltd	Kalani Venika Gunaratne, Amila Thibbotuwawa, Harsha Chamara Hewage, Alex Elkjaer Vasegaard	Benefits of Using Unmanned Aerial Vehicles of Last-mile Vaccine Delivery in Sri Lanka
Best Research in Postgraduate Research	SMEC International Pty. Ltd	Madushan Fernando, Amila Thibbotuwawa, H. Niles Perera	Comparing Different Metaheuristic Methods in Solving a Real-world Applications of Vehicle Routing Problem
Best Research Overall	South Asia Gateway Terminals (Pvt) Ltd	Erandi B.K. Herath, T. Sivakumar	Modelling the Level of Service of Bus Transportation - A Case Study in Sri Lanka