A NEW HYBRID METAHEURISTIC TECHNIQUE BASED ON GREY WOLF OPTIMIZATION, SYMBIOTIC ORGANISM SEARCH, AND ANT COLONY OPTIMIZATION FOR SOLVING MULTI-OBJECTIVE VEHICLE ROUTING PROBLEMS

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ABSTRACT

The Vehicle Routing Problem (VRP) presents a critical challenge in logistics and transportation, requiring optimisation techniques that minimise travel distances and costs while ensuring efficient delivery operations. The objectives of the multi-objective VRP addressed in this study are to minimise the total travel distance and the overall transportation cost. This study developed a hybrid metaheuristic algorithm involving grey wolf optimization, symbiotic organism search, and ant colony optimization (HMGSA) to address the multi-objective VRP. The hybridisation mechanism combines the global exploration strength of GWO, the solution refinement capability of SOS, and the effective path construction of ACO into an integrated search strategy. The algorithm was first developed and tested using a standard benchmark dataset (Dantzig42), which was selected due to its standard usage in VRP research and its suitability for performance comparison owing to its structured complexity. The results were followed by actual shipment data from PT Pos Indonesia's Boyolali to evaluate its consistency, computational efficiency, and solution quality. The real-world dataset consists of 19 delivery nodes, 2 available vehicles, and operational time-window constraints between 8:00 AM and 5:00 PM. Experimental results demonstrated that HMGSA consistently produced reliable, stable, and high-quality routing solutions across various configurations, with systematic convergence behaviour and effective minimisation of travel distance. The outcome of the first research objective shows that the algorithm exhibited strong performance in generating consistent optimisation outcomes with structured convergence and minimal performance fluctuation under both standard tests and real-world conditions. For objective two, three routing strategies were evaluated. Based on a single-vehicle optimal route, the algorithm provided the shortest distance, 91.74 km. However, the single-vehicle route has limited operational scalability. A hub-based Strategy was introduced to improve workload distribution at the expense of an increase in the total travel distance of 119.56 km. The Multi-Vehicle Routing Optimisation strategy proved the most operationally effective despite a longer distance of 182.23 km by allowing two vehicles to operate independently from a shared depot, achieving faster delivery and a balanced workload. Finally, for the third objective, five multi-objective optimisation strategies were applied. Among them, Performance-Based Adaptive Weighting emerged as the most effective technique, achieving the lowest multi-objective fitness score of 611,910.39 while maintaining route stability. Complementary approaches, including the Weighted Sum Method, Pareto-based Trade-Offs, Pareto Front Evaluation, and Hybrid Greedy HMGSA, further supported its performance. Beyond its application in the Boyolali case, validation through benchmark datasets and various optimisation strategies confirms that HMGSA can be applied to other logistics routing scenarios across different operational contexts. HMGSA has shown to be reliable and, therefore, an adaptable solution for various distribution systems. The findings also highlight the applicability of HMGSA in real-world courier services, contributing theoretically and practically to logistics optimisation. The hybrid approach presented in this study offers a scalable and adaptable solution for large-scale VRP problems, paving the way for future research on hybrid metaheuristics in logistics and supply chain management.

Keywords: Hybrid metaheuristics, Vehicle Routing Problem (VRP), Grey Wolf optimization, logistics optimisation, multi-objective optimisation

APPROVAL

This is to certify that this thesis conforms to acceptable standards of scholarly presentation and is fully adequate, in quality and scope, for the fulfilment of the requirements for the Degree of Doctor of Philosophy.

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DECLARATION

I hereby declare that the thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy is my own work and that all contributions from any other persons or sources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree at this or any other university. In making this declaration, I understand and acknowledge any breaches in this declaration constitute academic misconduct, which may result in my expulsion from the programme and/or exclusion from the award of the degree.

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