

OPTIMISING A WASTE MANAGEMENT SYSTEM USING ARTIFICIAL BEE COLONY (ABC) ALGORITHM

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Abstract

This study proposed the application of the Artificial Bee Colony (ABC) algorithm to address the Capacitated Vehicle Routing Problem (CVRP) in a real-world waste collection scenario. Effective waste management is critical for maintaining urban cleanliness and sustainability. Inefficient waste collection often suffers from inefficiency such as poor route planning, excessive travel distance and underutilization of vehicle capacity. The main objective is to minimise the total travel distance of collection vehicles while reducing carbon emission. The study adopted data from Qiao et al. (2020). The data contain a single depot, 47 waste collection points and 11 vehicles with maximum capacity of 80 tonnes. The ABC algorithm was selected due to its strong global search capabilities, simple structure and ability to balance between exploration and exploitation. The implementation of ABC algorithm consists of four phases which are initialisation, employed, onlooker and scout bee phases. Random insertion applied as a neighbourhood operator to enhance the local search capabilities within the algorithm. The result showed a total travel distance of 1408.25 km and a total waste load of 738 tonnes. Moreover, before optimisation, the total distance travelled was 1458.35 km which resulted in an estimation of 1397.1 kg CO₂. After optimisation, the overall distance decreased to 1408.35 km resulting in a reduction of CO₂ emission of 1348.8 kg CO₂. Overall, the proposed approach shows promise in enhancing the efficiency and responsiveness of real-world waste collection systems. Future work may focus on integrating real-time data, adjusting algorithm parameters and hybridizing ABC algorithm with other metaheuristics to further improve performance.

Keywords: *Waste Management System, Artificial Bee Colony Algorithm, Optimisation*

1. Introduction

Waste Management Systems (WMS) is a process that organisation use to collect, treat and properly dispose of waste (Peña et al., 2024). Hashemi-Amiri et al. (2023) mentioned that WMS often face inefficiencies due to poor route planning and rising waste volumes. It led to longer travel times, increased fuel consumption, and higher CO₂ emissions. This study addresses these issues by applying the ABC algorithm. The data used was adopted from Qiao et al. (2020) and consisted of one depot, 47 collection points and 11 vehicles with maximum capacity of 80 tonnes. The main objective of this study is to optimise a waste management system using ABC algorithm by minimising total distance of waste collection and reducing carbon dioxide emissions.

2. Methodology

This study implements the application of the ABC algorithm with the objective function to determine total distance of waste collection travelled by vehicles. The formulation of objective function considers the numbers of vehicles, number of waste collection points and the distance between these points along with the binary decision variables to define the routes travelled by each vehicle. The mathematical formulation of the objective function is adopted from Qiao et al. (2020). The ABC algorithm is implemented through four phases which are initialisation, employed bee, onlooker bee and scout bee phases. Each phase was designed to iteratively improve solution quality. The use of a random insertion as neighbourhood operator further enhanced local search capability. Besides reducing the overall distance travelled, this study will also look into the environmental cost of waste

collection through approximating the amount of carbon dioxide CO₂. The carbon dioxide emission is assumed to be the result of the travel distance accumulation and an emission factor. The CO₂ emissions can be calculated by using formula that adopted from Hashim et al. (2019).

3. Results / Findings

The outcomes demonstrated that the ABC algorithm successfully minimised the total distance travelled by each waste collection vehicle. The result showed a total travel distance for 11 vehicles is 1408.25 km and a total waste load is 738 t. Moreover, before optimisation, the total distance travelled was 1458.35 km which resulted in an estimation of 1397.1 kg CO₂. After optimisation, the overall total distance travelled decreased to 1408.35 km resulting in a reduction of CO₂ emission of 1348.8 kg CO₂. This decrease shows optimisation is not only effective in ensuring efficiency of routes but also helps in ensuring sustainability of the environment by reducing emissions.

4. Novelty of Research / Product / Project

This study introduces a novel application of the ABC algorithm to solve CVRP using data from Qiao et al. (2020). Through several metaheuristic methods like the Genetic Algorithm (GA), Particle Swarm Optimisation (PSO) and Ant Colony Optimisation that have been used in solving CVRP, the application of the ABC algorithm to this particular WMS scenario has been less explored (Szeto et al., 2011). According to them, the phases of the ABC algorithm provide unique combination of simplicity, global search and local refinement which make it suitable in solving the complex routing problem present in waste collection system. This study is able to prove both operation and environmental benefits of the algorithm through its application. This study successfully demonstrates a reduction in total distance and CO₂ emissions. This finding support ABC algorithm as viable and efficient method for real-world routing problems especially in urban waste collection.

5. Conclusion or Future Work

ABC algorithm was effective in optimising collection route with minimising total distance travel and carbon dioxide emissions. This approach improves operational efficiency and environmental impact. Future studies may focus on integrating real-time data, adjusting algorithm parameters or hybridizing ABC with other metaheuristics to further enhance waste collection performance and adaptability.

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