

**PENERAPAN DAN EVALUASI METODE-METODE BERBASIS
EVOLUTIONARY ALGORITHM DALAM PENYELESAIAN MASALAH
HETEROGENEOUS FLEET VEHICLE ROUTING PROBLEM WITH
REFRIGERATION AND 3D LOADING CONSTRAINTS: STUDI KASUS
DISTRIBUSI OBAT-OBATAN**

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Penelitian Vehicle Routing Problem (VRP) dalam konteks kesehatan belum membahas penentuan rute yang mempertimbangkan aspek temperatur penyimpanan kendaraan dan *3D Loading* yang terintegrasi. Penelitian ini bertujuan memformulasikan model VRP dengan armada heterogen berpendingin untuk distribusi obat-obatan dengan kendala pemuatan tiga dimensi, mengimplementasikan metode berbasis Evolutionary Algorithm (EA), dan mengusulkan skema *solution encoding and decoding* yang dapat merepresentasikan rute solusi serta menangani proses *3D loading*. Metode yang digunakan meliputi Genetic Algorithm (GA), Differential Evolution (DE), Biased Random Key Genetic Algorithm (BRKGA), dan Particle Swarm Optimization (PSO) yang dievaluasi menggunakan data historis perusahaan distribusi obat-obatan di Indonesia. Penelitian ini dibatasi pada data historis tanpa mempertimbangkan kondisi lalu lintas dan cuaca.

Hasil evaluasi menunjukkan bahwa GA menghasilkan performa optimal dengan penurunan *average total cost* sebesar 5.77% dibandingkan dengan metode lain. Akan tetapi, BRKGA menghasilkan performa tercepat dengan penurunan rata-rata waktu komputasi sebesar 43.52% dibandingkan dengan metode lain. Hasil ini menunjukkan bahwa *solution encoding and decoding scheme* yang diusulkan berhasil mengintegrasikan aspek *routing*, dan *3D loading* dengan hasil yang memuaskan yang dapat meningkatkan efisiensi perencanaan rute distribusi obat-obatan.

Kata-kata kunci: Vehicle Routing Problem, Evolutionary Algorithm, Distribusi Obat, 3D Loading, Heterogeneous Fleet, *Refrigeration*

IMPLEMENTATION AND EVALUATION OF EVOLUTIONARY ALGORITHM-BASED METHODS FOR SOLVING THE HETEROGENEOUS FLEET VEHICLE ROUTING PROBLEM WITH REFRIGERATION AND 3D LOADING CONSTRAINTS: A CASE STUDY OF PHARMACEUTICAL DISTRIBUTION

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Vehicle Routing Problem (VRP) research in the healthcare context has not addressed route determination that considers refrigeration aspects and 3D loading. This study aims to formulate a VRP model with heterogeneous refrigerated fleet for pharmaceutical distribution with three-dimensional loading constraints, implement Evolutionary Algorithm (EA)-based methods, and propose a solution encoding and decoding scheme that can represent route solutions and handle 3D loading processes. The methods used include Genetic Algorithm (GA), Differential Evolution (DE), Biased Random Key Genetic Algorithm (BRKGA), and Particle Swarm Optimization (PSO), which are evaluated using historical data from a pharmaceutical distribution company in Indonesia. This research is limited to historical data without considering traffic conditions and weather.

The evaluation results show that GA produces optimal performance with a reduction in average total cost of 5.77% compared to other methods. However, BRKGA produces the fastest performance with a reduction in average running time of 43.52% compared to other methods. These results demonstrate that the proposed solution encoding and decoding scheme successfully integrates routing and 3D loading aspects with satisfactory results that can improve the efficiency of pharmaceutical distribution route planning.

Keywords: Vehicle Routing Problem, Evolutionary Algorithm, pharmaceutical distribution, 3D loading, heterogeneous fleet, refrigeration