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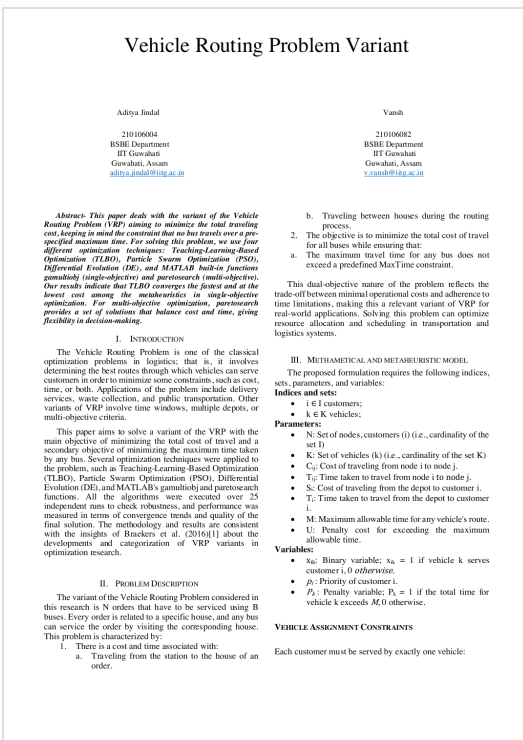

Vehicle Routing Problem Variant

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Abstract- This paper deals with the variant of the Vehicle Routing Problem (VRP) aiming to minimize the total traveling cost, keeping in mind the constraint that no bus travels over a pre-specified maximum time. For solving this problem, we use four different optimization techniques: Teaching-Learning-Based Optimization (TLBO), Particle Swarm Optimization (PSO), Differential Evolution (DE), and MATLAB built-in functions gamultiobj (single-objective) and paretosearch (multi-objective). Our results indicate that TLBO converges the fastest and at the lowest cost among the metaheuristics in single-objective optimization. For multi-objective optimization, paretosearch provides a set of solutions that balance cost and time, giving flexibility in decision-making.

I. Introduction

The Vehicle Routing Problem is one of the classical optimization problems in logistics; that is, it involves determining the best routes through which vehicles can serve customers in order to minimize some constraints, such as cost, time, or both. Applications of the problem include delivery services, waste collection, and public transportation. Other variants of VRP involve time windows, multiple depots, or multi-objective criteria.

This paper aims to solve a variant of the VRP with the main objective of minimizing the total cost of travel and a secondary objective of minimizing the maximum time taken by any bus. Several optimization techniques were applied to the problem, such as Teaching-Learning-Based Optimization (TLBO), Particle Swarm Optimization (PSO), Differential Evolution (DE), and MATLAB's gamultiobj and paretosearch functions. All the algorithms were executed over 25 independent runs to check robustness, and performance was measured in terms of convergence trends and quality of the final solution. The methodology and results are consistent with the insights of Braekers et al. (2016)[1] about the developments and categorization of VRP variants in optimization research.

II. Problem Description

The variant of the Vehicle Routing Problem considered in this research is N orders that have to be serviced using B buses. Every order is related to a specific house, and any bus can service the order by visiting the corresponding house. This problem is characterized by:

1. There is a cost and time associated with:
   a. Traveling from the station to the house of an order.
   b. Traveling between houses during the routing process.
2. The objective is to minimize the total cost of travel for all buses while ensuring that:
   a. The maximum travel time for any bus does not exceed a predefined MaxTime constraint.

This dual-objective nature of the problem reflects the trade-off between minimal operational costs and adherence to time limitations, making this a relevant variant of VRP for real-world applications. Solving this problem can optimize resource allocation and scheduling in transportation and logistics systems.

III. Methametical and metaheuristic model

The proposed formulation requires the following indices, sets, parameters, and variables:

Indices and sets:

- $i \in I$ customers;
- $k \in K$ vehicles;

Parameters:

- N: Set of nodes, customers (i) (i.e., cardinality of the set I)
- K: Set of vehicles (k) (i.e., cardinality of the set K)
- C_{ij}: Cost of traveling from node i to node j.
- T_{ij}: Time taken to travel from node i to node j.
- S_i: Cost of traveling from the depot to customer i.
- T_i: Time taken to travel from the depot to customer i.
- M: Maximum allowable time for any vehicle's route.
- U: Penalty cost for exceeding the maximum allowable time.

Variables:

- x_{ik}: Binary variable; $x_{ik} = 1$ if vehicle k serves customer i, 0 *otherwise*.
- p_i : Priority of customer i.
- P_k : Penalty variable; $P_k = 1$ if the total time for vehicle k exceeds M, 0 otherwise.

Vehicle Assignment Constraints

Each customer must be served by exactly one vehicle: