Jurnal Kejuruteraan 33(1) 2021: 63-72
https://doi.org/10.17576/jkukm-2020-33(1)-07

Three-Axes Rotation Algorithm for the Relaxed 3L-CVRP

Irma-Delia Rojas-Cuevas [a,b*], Santiago-Omar Caballero-Morales[b], Diana Sánchez-Partida[b] & José-Luis Martínez-Flores[b]

[a]*Systems and Computation*
Instituto Tecnologico de Puebla, Puebla, Mexico

[b]*Postgraduate department of Logistic and Supply Chain Management,*
Universidad Popular Autonoma del Estado de Puebla A.C., Puebla, Mexico

**Corresponding author: irmadelia.rojas@upaep.edu.mx*

Received 23 April 2019, Received in revised form 29 March 2020
Accepted 01 June 2020, Available online 28 February 2021

ABSTRACT

The purpose of this work is to present a developed three-axes rotation algorithm to improve the solving methodology for the relaxed 3L-CVRP (Three-Dimensional Capacitated Vehicle Routing Problem). Although there are reported works on solving approaches for the relaxed 3L-CVRP that consider product rotation to optimize load capacity, rotation on the three axes has not been thoroughly studied. In this aspect, the present work explicitly explores the three-axes rotation and its impact on load capacity optimization. In order to improve the relaxed 3L-CVRP problem, a two-phase solution was developed. The first phase consists of finding the solution for the CVRP problem, using a demand previously obtained with a heuristic developed to convert the 3L-CVRP demand into CVRP demand. The second phase is to obtain the loading of the vehicle using a heuristic developed to load the items using rules to obtain the rotation of the items. The proposed approach was able to improve the load assignment in 48.1% of well-known 3L-CVRP instances when compared to similar approaches on the relaxed 3L-CVRP. The outcomes of this research can be applied to transportation problems where package rotation on the z-axis is an option, and there are not fragile items to load in the vehicles.

Keywords: 3L-CVRP; constraint relaxation; three-axes rotation; load capacity optimization

INTRODUCTION

The Capacitated Vehicle Routing Problem (CVRP), proposed by (Dantzig & Ramser 1959), is a Non-deterministic Polynomial-time complexity class problem (NP-hard) in the transportation field. The CVRP consists of defining routes for every vehicle to minimize transportation costs or time with the restriction of capacity based on the weight or volume of the items. The problem has been addressed by different researchers using metaheuristic alternatives (Caballero-Morales, Martínez-Flores & Sánchez-Partida 2018; Hosseinabadi, Rostami, Kardgar, Mirkamali & Abraham 2017; Mazidi, Fakhrahmad & Sadreddini 2016) to obtain near-to-optimal solutions to large instances (>150 nodes or locations to be served by the vehicle) within a reasonable time. In contrast, exact algorithms can only provide solutions for instances with less than 137 nodes (Liu, Li, Luo & Chen 2013). Orrego (Orrego Cardozo, Ospina Toro, & Toro Ocampo, 2016) presents various metaheuristics used to solve CVRP. Recently, this type of problem evolved considering the transport of items of different sizes (dimensions), known as the Three-Dimensional Capacitated Vehicle Routing Problem (3L-CVRP) introduced by Gendreau (Gendreau, Iori, Laporte & Martello 2006). This problem is a combination of the CVRP and the Three-Dimensional Bin Packaging Problem (3D-BPP). The 3D-BPP has been solved to optimality for instances with a maximum transportation load of 60 items(Martello, Pisinger, & Vigo, 2000).

Because the 3L-CVRP takes into account the dimensions of the items, not all items are suitable to be loaded within the vehicle. The loading task increases in complexity as more constraints are considered (i.e., LIFO, support, fragility). Because of the complexity of the transportation scenario, some or all constraints are relaxed. It leads to Relaxed 3L-CVRP.

The present work extends on the solving aspect of the Relaxed 3L-CVRP by proposing an algorithm to improve the loading task. It is performed by extending the three-axes rotation of the items and performing constraint relaxation on fragility, support area, and LIFO. Relaxation was performed as in the reported reviewed works, and it was found that three-axes rotation can improve load assignment and support area. Particularly, load assignment was improved in 48.1% of well-known 3L-CVRP instances when compared to similar approaches.

The advances of the present work are described as follows: in 3L-CVRP Section the technical background of the 3L-CVRP is presented; then in the next section recent works on the 3L-CVRP and Relaxed 3L-CVRP are presented and discussed; after the proposed algorithm is described; immediately the obtained results and the discussion of the