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The Multi-Vehicle Cyclic Inventory Routing Problem: Formulation and a Metaheuristic Approach

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Abstract: This paper presents a new variant of the Multi-Vehicle Cyclic Inventory Routing Problem (MV-CIRP) which aims to determine a subset of customers to be visited, the appropriate number of vehicles used, and the corresponding cycle time and route sequence, such that the total cost (e.g. transportation, inventory, and rewards) is minimized. The MV-CIRP is formulated as a mixed-integer nonlinear programming model. We propose a Simulated Annealing (SA) based algorithm to solve the problem. SA is first tested on the available benchmark Single-Vehicle CIRP (SV-CIRP) instances and compared to the state-of-the-art algorithms. SA is then tested on the benchmark MV-CIRP instances and compared to optimization solver and a standard Iterated Local Search (MV-ILS) approach. Experimental results show that SA is able to obtain 9 new best known solutions when solving the SV-CIRP instances and outperforms both the optimization solver and the MV-ILS when solving the MV-CIRP instances. Furthermore, insights in the complexity of the MV-CIRP are discussed and illustrated.

Keywords: multi-vehicle, cyclic inventory routing problem, simulated annealing

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1. Introduction

The Inventory Routing Problem (IRP) deals with a case where the costs occurring in a supply chain network (e.g. the transportation and inventory costs) are taken into consideration simultaneously. This is based on the Vendor Managed Inventory (VMI) policy (Waller et al., 1999), in which the supplier takes the full responsibility to manage its customers' inventory by deciding the time and quantity of each delivery. This policy has been proven to improve the overall performance of a supply chain network (Zhong and Aghezzaf, 2011).

The Cyclic Inventory Routing Problem (CIRP) is a variant of the general IRP where the customers are assumed to have a stable demand rate over an infinite planning horizon. Therefore, the aim is to find a cyclic distribution plan for a set of customers such that the long term transportation and inventory costs are minimized (Raa and Aghezzaf, 2009). The Single-Vehicle CIRP (SV-CIRP) is arisen as the subproblem of the CIRP where it is not mandatory to visit every customer and thus an appropriate subset of customers should be selected. Another important property is that the single vehicle has a capacity limit and is therefore allowed to make multiple trips from the depot on a given day. In this case, an appropriate vehicle cycle time, which is the lead time between two consecutive deliveries to a customer, must as well be decided. No strict upper bound for this cycle time value is considered. Actually, such an upper bound would only make the problem easier to solve due to a smaller number of possible solutions (Vansteenwegen and Mateo, 2014). The SV-CIRP has been well studied (Vansteenwegen and Mateo, 2014, Zhong and Aghezzaf, 2012, Lefever et al., 2016).

Gunawan et al. (2019) introduced the MV-CIRP with a fixed number of vehicles in a short conference paper. In the current paper, we present a more difficult, but also more realistic, version by treating the number of vehicles as a decision variable. This model is suitable for logistics companies which own a large number of vehicles. Instead of utilizing all of their vehicles, it is more beneficial to only use the most appropriate number of vehicles. In other words, not all available vehicles must be utilized to serve the customers. A subset of vehicles is selected by making the trade-off between fixed vehicle costs and variable costs (e.g. vehicle's traveling cost, inventory cost, and reward in this problem). This consideration has not been studied before and is considered explicitly in this paper to fill a gap in the CIRP literature. We further show the advantages of the MV-CIRP discussed in this paper compared to the variant