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On a Pickup to Delivery Drone Routing Problem: Models and algorithms

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ABSTRACT

A new variant of the Pickup and Delivery Routing problem is presented. Given a set of customers, facilities, a depot, and a homogeneous fleet of drones, the Pickup to Delivery Drone Routing Problem (PDDRP) aims to find a drone scheduling such that a drone serves the customer's order from a set of available facilities. Each drone starts in the depot, flies to pickup the customer's order in a facility, and continues its flight to deliver the parcel to a customer. Then, the drone begins another service, and once its last service is completed, it returns to the depot. The objective is to minimize the makespan associated with the drone fleet. The layer of facilities forcing drones to visit one of them to pickup the parcel makes the problem different from traditional pickup and delivery routing problems. Three mixed-linear programming models are presented to obtain optimal solutions for the problem. The first model is related to the multiple Traveling Salesman Problem (m-TSP), the second is associated with the Parallel Machine Scheduling Problem (PMS), and the third was developed specifically for the new problem.

Given the high computational complexity of the PDDRP, a Greedy Randomized Adaptive Search Procedure (GRASP) was designed to find near-optimal solutions when exact approaches cannot achieve (near) optimal solutions. Computational experiments show that a commercial solver could solve only small problem instances. GRASP can find reasonable solutions in a short time when medium and large instance sizes need to be solved. Finally, is shown that some routing problems for delivery, allowing truck-drone collaboration, could be formulated as an extension of PMS.

1. Introduction

1.1. Context and motivation

The Vehicle Routing Problem (VRP) has been well studied in the literature; see Braekers et al. (2016), Golden et al. (2008), Toth and Vigo (2014) and Vidal et al. (2020), where problems, models, algorithms, and applications are presented. The richness of this class of discrete optimization is awesome. In the last decades, due to e-commerce, mainly the operation of last-mile delivery has forced the study of different logistic problems. A central problem in this context is the planning of vehicle routing for delivery, assuming that the problem of depot location and the size of the vehicle fleet were already solved. Thus, depending on several factors like the location and number of customers, the type of vehicles conforming to the vehicle fleet, and the type of operations to be executed by the vehicles, the application of VRP models in the real world is fundamental. Unmanned Aerial Vehicles (UAVs), more known as Drones, have started to participate in parcel delivery in the last few years. The use of drones has greatly developed in the last years. Their use in Agriculture, Surveillance, and Delivery have been well known in the literature. Several surveys have made evident the rapid evolution of the literature about it. Some of they are, Chung et al. (2020), Khoufi et al. (2019), Macrina et al. (2020), Moshref-Javadi and Winkenbach (2021), Otto et al. (2018), Rojas-Viloria et al. (2021) and Shakhatreh et al. (2019). Particularly, the study of delivery by drones and trucks in tandem has been intensively developed since Murray and Chu (2015). Models, algorithms, and applications have been studied specifying different variants in routing problems using a truck-drone system, and it is still a hot area. The study of routing problems using only a fleet of drones has had an increasing interest in the scientific community, principally related to some applications, for example, in Healthcare (Ghelichi et al., 2021; Hii et al., 2019; Jiang et al., 2021; Sedov et al., 2020) and Humanitarian Logistics (Akram et al., 2020; Ejaz et al., 2020; Holzmann et al., 2021).

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