A Branch-and-Price algorithm for a routing problem with inbound and outbound requests

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1 Introduction

The studied problem arises in the context of non-emergency transportation of patients. We consider a hospital (the depot) and a set of patients with a medical appointment. Patients require either to go from home to hospital (inbound request) or from hospital to home (outbound request). The problem can be addressed either as a Pickup and Delivery Problem or as a special Multi-Trip Vehicle Routing Problem because for any request the depot is either the pickup or the delivery node. The problem is called Multi-Trip Vehicle Routing Problem with Mixed Pickup and Delivery, and Release and Due dates (MTMPD-RD).

Seen as a multi-trip VRP, the problem raises a complex time and vehicle capacity management but we adopt this standpoint and prove that the multi-trip model outperforms the Pickup and Delivery model.

2 Problem description

The MTMPD-RD is stated as follows. We dispose of a fleet of homogeneous capacitated vehicles $\mathcal{M}$ (of capacity Q) to serve a set $\mathcal{N}$ of transportation requests to/from a single hospital (the depot). We distinguish two types of requests : inbound and outbound requests. Inbound requests consist in transporting patients from their home to the hospital, while outbound requests consist in transporting patients from the hospital to their home. With each request $i \in \mathcal{N}$ are associated a release date r_i (time at which the patient is available at the pickup location), a due date d_i (latest time at which the patient can be dropped off at the delivery location), and a service time s_i at customer location.

Because of these constraints, drivers are enforced to come back regularly to the hospital to perform multiple trips within the planned period. A service time might also be spent at the depot, for pickups and drop-offs. When starting a new trip, if it contains at least one outbound request, a pickup service time T_P must be added, and when ending a trip, if it contains at least one inbound request, a delivery service time T_D must be added. The objective is to minimize the total cost while scheduling routes for drivers in order to satisfy patients' requests.

3 Solution method

We propose a first Branch-and-Price algorithm to solve the studied problem. In this approach, we explicitly consider the fact that all requests are connected with the hospital. The problem is viewed as a multi-trip vehicle routing problem with specific capacity and time constraints. We denote the algorithm as MT-BP. The specific constraints have consequences both on the pricing problem and on the branching rules. For the pricing problem, we propose an original definition of resources with adapted extension rules. For branching rules, we use the classical ones enriched with an original technique to deal with the multiple trips configuration.

Our approach (MT-BP) is compared to an approach in which our problem is modeled as a Pickup and Delivery Problem (denoted PD-BP). In this approach, a classical Branch-and-Price algorithm to solve a Pickup and Delivery Problem with Time Windows [1] in which the hospital is duplicated for each requests is used.

4 Experimental results and perspectives

Experiments are conducted on a benchmark of realistic instances extracted from the city of Aix-en-Provence, France. Four series of instances are generated with 50 or 100 customers and two types of vehicles : sedan ($Q = 2$) and minivan ($Q = 4$). Series of instances are named $S_{n/t}$ where, n is the number of requests (50 or 100) and t is the vehicle type (s for sedan or m for minivan). Each series is composed of 15 instances. The computational time is limited to 7,200 seconds.

On these instances, MT-BP largely outperforms PD-BP. It finds more feasible solutions (in total 52 against 43) and more optimal solutions (in total 46 against 30). For most instances, the running time to compute the lower bound at the root node and the running time to proven optimality are better.

To further validate the MT-BP, we adapted it for the solution of a well known problem of the literature, the Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows (VRPSPDTW) [2]. Our experiments on benchmark instances closed the benchmark for small instances and closed four 100-customers instances. We also detected that an infeasible solution was published in the literature.

Finally, we evaluated the opportunity to tackle the problem as a mono-trip vehicle routing problem followed by a trip-to-vehicle assignment. Experiments show the computational interest but also the limits of this standpoint as it is difficult to be sure in advance that the solution provided by the mono-trip variant would comply with the fleet size.

A first perspective for this work would be to propose heuristics to be able to solve larger instances, which would be appreciated in real-life applications. Another perspective is to integrate equity in a planning horizon of several periods.

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Références

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