A Branch-and-Price algorithm for a medical transportation problem

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1 Introduction

In medical services, some cares are performed at patients' homes but most of the time, they are performed at the hospital. The majority of patients can go back and forth to the hospital by their own to get cares. However, some disabled or old patients cannot go to hospital by their own. In this context, transport companies are involved to provide medical transportation of patients. In this work, we assume that a single company is involved with a limited number of drivers. Also, patients have to be picked up after a release date and to be dropped off before a due date. These two constraints limit the time a patient can spend in the medical transport and enforce the use of multiple trips. We assume the demand in terms of transportation requests is daily revealed on a time horizon of several days. In practice, there exists service provider platforms to help managing the schedule of such routes and the assignment of routes to drivers. Generally, the used algorithms within these platforms are based on simple assignment rules (e.g. the FIFO rule "First In First Out"). These rules can be inefficient for large scale transportation systems or when the demand varies strongly. Another drawback of these rules is that they create inequities between drivers in terms of route cost (duration or distance) and/or painfulness of work.

The literature on equity in vehicle routing is relatively poor. Matl et al. (2018) [1] proposed a state of the art on routing problems involving equity. The same authors proposed a deeper study highlighting the importance of the choice of the metric to balance [2]. In our study, equity should be ensured for a time horizon of several periods and the schedule of routes is established for each period. The purpose of this work is to propose a formulation for the single period problem and to develop an efficient solution method. Equity over the whole time horizon will be considered in further research.

2 Problem statement and solution method

Our problem is stated as follows. A fleet of homogeneous capacitated vehicles serves a set of transportation requests to/from a single hospital. We distinguish two types of requests: inbound and outbound requests. Inbound requests consist in transporting patients from their home to the hospital. Outbound requests consist in transporting patients from the hospital to their home. With each request are associated a release date (at the pickup location), a due date (at the drop off location), and a service time. Each patient must be picked up after its release date and dropped off before its due date. Because of these constraints, drivers are enforced to come back regularly to the hospital to perform multiple trips within the planned period. The objective is to minimize the total cost while scheduling routes for drivers in order to satisfy patients' requests.

In our approach (MT-BP) we use a 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. This specificity has consequences on the pricing problem and the branching rules. In 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 modelled as Pickup and Delivery Problem (denoted PD-BP). In this approach, a classical Branch-and-Price algorithm to solve a Pickup and Delivery Problem is used.

3 Experimental results and perspectives

Experiments are conducted on a benchmark of realistic instances extracted from the city of Aix-en-Provence. Obtained results show that MT-BP outperforms PD-BP on most instances. In addition, MT-BP is able to solve instances with up to 100 requests. The main perspective of this work is to integrate equity in a planning horizon of several periods.

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References

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