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Manpower allocation and vehicle routing problem in non-emergency ambulance transfer service

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ABSTRACT

We present a manpower allocation and vehicle routing problem (MAVRP), which is a real-life healthcare problem derived from the non-emergency ambulance transfer service in Hong Kong public hospitals. Both manpower and vehicles are critical resources for the hospitals in their daily operations. The service provider needs to make an effective schedule to dispatch drivers, assistants and ambulances to transport patients scattered in different locations. We formulate the MAVRP into a mathematical programming model and propose several variable neighborhood search (VNS) algorithms to solve it. We tested the VNS with steepest descent, first descent and a mixed of two descent strategies on the MAVRP instances. The computational results demonstrate the effectiveness and efficiency of the VNS algorithms. Moreover, we also conducted additional experiments to analyze the impact of the number of vehicles on the solutions of the MAVRP instances.

1. Introduction

This research studies a manpower allocation and vehicle routing problem (MAVRP), which is originated from the hospital environments. Manpower and vehicles are critical resources for the hospitals in maintaining their daily operations, especially in transporting patients everywhere. It is of great importance to well organize these resources so as to increase the effectiveness and reduce the operational costs of the hospitals.

As a typical example, a public hospital in Hong Kong provides the non-emergency ambulance transportation service. The service provider arranges drivers, assistants and ambulances to pick up elderly or disabled patients from home to clinics. The patients make requests at different places for the ambulance transportation. The patients could have different types of disabilities. Some patients who cannot complete the treatment process independently may be accompanied by their family members, so one or more seats will be reserved for one request. Moreover, some injured patients who cannot move without wheelchairs or stretchers may require special assistance. The ambulance vehicle provides adaptive seats that can be converted to beds and wheel chairs (see Fig. 1). In this case, besides drivers, additional assistants have to be staffed on the ambulance to handle wheelchairs or carry stretchers.

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(a) (b)

Fig. 1. Adaptive seats in an ambulance.

To fulfill the patients' requests, the planner of the service provider needs to consider the following two issues simultaneously: (1) deploying a number of staff members on each ambulance; (2) designing a route for each ambulance to transport patients. The goal of the plan is to optimize the financial expenditure, which roughly consists of three parts: (1) the penalty costs of the unfulfilled requests (such requests are outsourced to external communities with additional costs); (2) the costs of deploying manpower on ambulances; and (3) the total travelling costs of each ambulance.

Fig. 2 illustrates an example of the MAVRP, where two ambulances are situated at the hospital and 8 requests are scattered in different locations. The ambulance has a limited capacity C of seats, e.g., $C = 12$. Patient request 1 reserves for 2 seats and requires 2 staff members. Other patient requests can be found in this figure. If the first ambulance serves patients 1, 2, 3 and 4, at least 3 staff members must be deployed, which is the maximum number of staff demands among 4 patient requests. Therefore, patients occupy 8 seats, staff members occupy 3 seats and 11 seats are occupied in total. Note that patient request 8 is unfulfilled and has to be outsourced.

The MAVRP extends the traditional vehicle routing problems (VRPs) by incorporating with the allocation of manpower for each vehicle. The vehicle load is constituted by both staff members and so-called customers (patients with their family members). The contributions of this paper are threefold. First, we introduce a new and practical planning and routing problem that simultaneously optimizes the resources of both manpower and vehicles. Second, we formulate the problem as an integer programming model and propose effective heuristic algorithms for solving the problem. Third, we modify the datasets from traditional capacitated VRP (CVRP) data sets to generate the MAVRP instances. The comprehensive experimental results can serve as a baseline for future research on this work or other related problems.

The remainder of this paper is organized as follows. In Section 2, we briefly describe the relevant literature on the MAVRP. We then provide a formal definition of the MAVRP in Section 3. In Section 4, we introduce variable neighborhood search (VNS) algorithms for solving this problem. To evaluate our approaches, Section 5 reports results of the experiments that

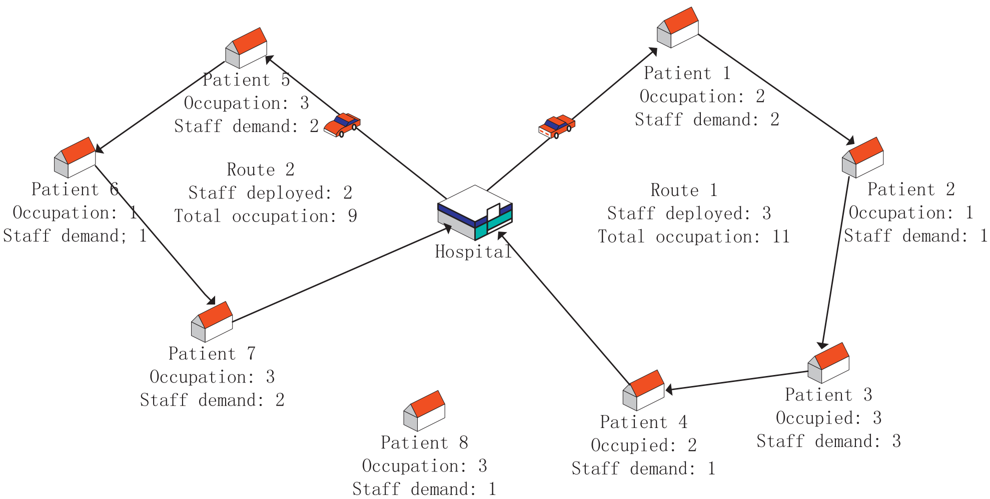

Fig. 2. An example of the manpower allocation and vehicle routing problem.