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Discrete Optimization

Vehicle routing and crew scheduling for metropolitan mail distribution at Australia Post

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Abstract

This paper presents a new multi-depot combined vehicle and crew scheduling algorithm, and uses it, in conjunction with a heuristic vehicle routing algorithm, to solve the intra-city mail distribution problem faced by Australia Post.

First we describe the Australia Post mail distribution problem and outline the heuristic vehicle routing algorithm used to find vehicle routes. We present a new multi-depot combined vehicle and crew scheduling algorithm based on set covering with column generation. The paper concludes with a computational investigation examining the affect of different types of vehicle routing solutions on the vehicle and crew scheduling solution, comparing the different levels of integration possible with the new vehicle and crew scheduling algorithm and comparing the results of sequential versus simultaneous vehicle and crew scheduling, using real life data for Australia Post distribution networks.

Keywords: Integer programming; Vehicle routing; Vehicle scheduling; Crew scheduling

1. Introduction

Vehicle routing and crew scheduling are part of many general distribution problems commonly faced by freight distribution and postal organisations. The traditional planning process used to find solutions to problems of this type typically involves constructing a set of vehicle routes then building a set of crew schedules to cover all vehicle routes and assigning vehicles to a set of vehicle routes to produce vehicle schedules.

The main contribution of this paper is a new mathematical formulation integrating the vehicle and crew scheduling stages of the planning process which is solved using an algorithm based on set covering with column generation.

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Section 2 reviews the literature on integrated vehicle and crew scheduling. Section 3 gives a description of the intra-city vehicle routing and crew scheduling problem faced by Australia Post. Section 4 describes the heuristic vehicle routing algorithm used to construct vehicle routes. Section 5 describes the new vehicle and crew scheduling algorithm used to create vehicle and crew schedules. Section 6 undertakes a computational investigation examining the affect of different types of vehicle routing solutions on the vehicle and crew scheduling solution, and compares the different levels of integration possible with the new vehicle and crew scheduling algorithm, using data for the Australia Post Melbourne metropolitan mail distribution problem.

2. Literature review

Freling et al. (2003) and Haase et al. (2001) provide a good overview of methods for *partially* integrating vehicle and crew scheduling for the related problem of mass transit crew scheduling.

Full integration of vehicle and crew scheduling, so called simultaneous vehicle crew scheduling (referred to as either the single or multiple depot simultaneous vehicle crew scheduling problem—SDSVCSP, MDSVCSP, respectively) has only recently been considered in the literature. There are some papers that consider the SDSVCSP though relatively few that consider the MDSVCSP.

Haase and Friberg (1999) present an exact algorithm for the SDSVCSP using set partitioning with column generation, however, only very small problems were able to be solved (<30 trips). Haase et al. (2001) and Freling et al. (2003) consider the SDSVCSP in urban mass transit with a homogeneous vehicle fleet and two crew types where trip start and end times are fixed by a timetable. The approach presented by Haase et al. (2001) uses set partitioning with column generation and was used to solve problems with up to 400 tasks optimally and 700 tasks heuristically. Freling et al. (2003) use Lagrangian relaxation with column generation to find solutions for a set partitioning based model and solve problems with up to 238 tasks.

Huisman et al. (2003) extend the work of Freling et al. (2003) to the multiple depot case. They present two similar formulations for the MDSVCSP, incorporating variables for both crew schedules and vehicle *arcs*. Problems with up to 650 trips were solved using Lagrangian relaxation with column generation with the extra restrictions that: drivers are only allowed to operate vehicles stationed at their home depot; a maximum of only one vehicle change is permitted in a crew schedule, significantly simplifying the column generation sub algorithm; and not all trips can be driven by a vehicle operated out of any depot.

Klabjan et al. (2002) and Cordeau et al. (2001) solve a similar problem for aircraft routing and crew scheduling. Airline planning consists of several stages. The first stage is called Schedule Planning, deciding when and where to fly, the next stage is called Fleet Assignment where aircraft types are assigned to the schedule. The next stage involves finding a feasible set of aircraft routes, and the final stage is the crew scheduling stage which involves finding crew schedules and pairings, where a pairing is a sequence of crew schedules starting and ending at the same base and spanning less than a week.

For the problem considered by Klabjan et al. (2002) the Fleet Assignment stage of the planning process has been completed, dictating the number of aircraft on the ground at any one time. The crew scheduling formulation they present includes aircraft counting constraints to ensure that the crew schedules they develop adhere to the number of aircraft available, and in addition, allow small changes in the flight schedule in order to find better crew scheduling solutions.

Similarly, for the problem considered by Cordeau et al. (2001) the Fleet Assignment stage of the planning process has been completed, so that the type of aircraft assigned to each flight leg is known. They use Benders decomposition with column generation to solve problems where crew are only allowed to fly a single type of aircraft meaning that the problem decomposes into separate problems for each aircraft type. Problems with up to 500 flight legs were solved using this technique.

The simultaneous vehicle crew scheduling formulation we present is new in many respects: it is