

# Hybrid Column Generation Approaches for Solving Real World Crew Management Problems<sup>†</sup>

Tallys H. Yunes  
tallys@acm.org

Arnaldo V. Moura  
arnaldo@ic.unicamp.br

Cid C. de Souza  
cid@ic.unicamp.br

Instituto de Computação, Universidade Estadual de Campinas  
Caixa Postal 6176, CEP 13083-970, Campinas, SP, Brazil

## Abstract

This article considers the overall crew management problem that arises from the daily operation of an urban transit bus company that serves the metropolitan area of the city of Belo Horizonte, in Brazil. Due to its complexity, the problem is divided in two distinct problems: *crew scheduling* and *crew rostering*. We have tackled each one of these problems using Mathematical Programming (MP) and Constraint Logic Programming (CLP) approaches. Besides, we also developed hybrid column generation algorithms for solving these problems, combining MP and CLP. The hybrid algorithms always performed better, when obtaining optimal solutions, than the two previous isolated approaches. In particular, it proved much faster for the scheduling problem. All the proposed algorithms have been implemented and tested over real world data obtained from the aforementioned company. The coefficient matrix of the linear program associated with some instances of the scheduling problem contains tens of millions of columns, and this number is even larger for the rostering problem. The analysis of our experiments indicates that it was possible to find high quality, and many times optimal, solutions that were suitable for the company's needs. These solutions were obtained within reasonable computational times, on a typical desktop PC.

## Introduction

The overall *crew management* problem concerns the allocation of trips to crews within a certain planning horizon. In addition, it is necessary to respect a specific set of operational constraints and minimize a certain objective function. Being a very hard problem, when taken in its entirety, it is usually divided in two smaller problems: the *crew scheduling* problem and the *crew rostering* problem (see [6]). In the crew scheduling problem, the aim is to partition the initial set of trips into a minimal set of *feasible duties*. Each such duty is an ordered sequence of trips which is to be performed by the same crew and that satisfies a subset of the original problem constraints: those related to the sequencing of trips during a workday. The crew rostering problem takes as input the set of duties output by the crew scheduling phase and builds a roster spanning a longer period, e.g. months or years. In the latter case, the roster must satisfy a different set of constraints: those related to rest periods, vacations and other long term operational restrictions.

This article describes the crew management problem stemming from the operation of a Brazilian bus company that serves a major urban area, with more than 2 million inhabitants, in the city of Belo Horizonte, in Brazil. As employee wages may well rise to 50 percent or more of the company's total expenses, even small percentage savings can be quite significant. The related crew scheduling and crew rostering problems are solved with hybrid column generation approaches involving both Integer Programming (IP) and Constraint Logic Programming (CLP) techniques. We also present pure IP and CLP solutions for these problems.

To harness the capabilities of both the IP and CLP techniques, we resorted to a hybrid approach to solve larger problem instances. This algorithm secures the strengths of both the pure IP and the pure CLP approaches: only a small subset of all the feasible duties is efficiently dealt with at a time, and new feasible

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