A Decision Support Framework for the Airline Crew Schedule Disruption Management with Strategy Mapping

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Abstract. Disruption management for airline crew schedules is important for the airline industry, since an increasing amount of disruptions to the regular operations occur frequently. The emphasis of this task is put on quickly obtaining one or more reasonable, at best optimal, recovery solutions from current disruptions, which has to be achieved within an acceptable time period. In this work, we propose a decision support framework that combines exact optimization methods and meta-heuristics for solving real-life practical problems. An exact method, based on a Column Generation type of procedure, is studied and tested, while a dedicated Genetic Algorithm working with a local improvement procedure provides the capability to solve the problem alternatively. Notably, a so-called *strategy mapping* procedure is applied to customize solution methods.

1 Introduction

Due to the uncertain operating environment, numerous factors potentially influence the actual operations, such as aircraft breakdowns, severe weather, crew sickness, air congestion etc. As a result, frequent perturbations of flight and crew schedules occur everyday in airlines. *Crew Recovery* hence is the process by which airlines react to disruptions, and recover the crew schedule in a way that minimal 'impact' is produced by the disruption situation.

Similar to the airline crew scheduling (CSP) process, the recovery attempts to reschedule all the flights that are disrupted by irregular events. However, the airline Crew Recovery Problem (CRP) has been studied comparably little from a research point of view. Lettovský et al. [4] developed a framework using a pairing generation method that incorporates special branching strategies. A systematic study has been conducted by Stojković et al. [7], in which they solved it as an integer nonlinear multi-commodity network flow model with time windows and additional constraints. In addition, Yu et al. [8] described an award-winning real-life application employed by Continental Airline in the U.S., which treated the problem as a set covering problem, and a so-called *generate-and-test* heuristic was applied for roster

generation. Moreover, some studies about airline irregular operations are also discussed in [3] and [5].

In this approach we propose a decision support framework. It provides a bundle of methods. A preprocessing procedure is developed to identify the suitable strategy, and customize it for the given situation. It shows that the selected strategy produces normally better solutions, and the solution time can be reduced.

In Section 2 we describe the airline CRP in detail and the relevant model is presented. The framework and solution methods are described in Section 3. In Section 4 a case study is presented to test the mapping strategy and the proposed solution methods.

2 Crew Recovery Problem

The process associated with the CRP takes care of disrupted situations in which original crew schedules require several, sometimes major, modifications to keep the airline's operations running after an unplanned occurrence. When disruptions happen, a series of flights have to be delayed and even canceled, and additional crews and flights are required in order to have enough resources to service all the flights that need to be operated.

2.1 Problem Description

At least three kinds of resources must be recovered during a disrupted time period: aircraft, crew, and passengers. Each of them implies large impact to the new schedule. For example, a shortage of aircrafts will result in not only unexpected delays and cancelations, but also some additional difficulties which makes the crew recovery more difficult to solve. Due to the complexity of the problem, common approaches will normally be decomposed into several sequential sub-problems, whereas each of them will handle with one resource type respectively. The way to decompose the problem differs from airline to airline regarding the heterogeneous company rules. One reason for applying a sequential approach is the fact that a complete integration is unrealistic from a practical point of view. However, a tightly integrated approach is obviously the work that needs to be done in the near future, because of allowing interactive collaboration among them.

2.2 Problem Formulation

In this approach the airline CRP is formulated as a set partitioning type model, where a set of affected flights caused by disruptions needs to be assigned or reassigned. These disrupted flights grouped with previously planned flights (flights set F) are chained into a set of rosters R, which represent all the possible individual schedules for a set of crew members W within a certain