Increasing Stability of Crew Schedules in Airlines

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In airline traffic disruptions occur frequently and cannot be totally avoided. They may lead to infeasible aircraft and crew schedules during the day of operations, due to absence of resources or violation of crew rules. The process of finding new schedules in such cases is called recovery or disruption management. The short-term recovery actions usually imply additional costs meaning that the total operational costs of a crew schedule can be significantly higher than the original planned costs. It is generally desirable to construct the schedule already in the planning phase in such a way that not just the planned costs, but the total operational costs are minimized. The goal is thus to construct schedules which remain feasible or can be recovered without high costs in cases of disturbances. This approach is generally called robust scheduling.

There is no unique definition about robustness in airline scheduling. From our point of view it is important to realize that robustness involves the two aspects stability and flexibility. A schedule is *stable* if changes in operating environment imply only small changes in the schedule. For example delays can to a large extent be absorbed by buffer time at the right place without propagating them further. On the other hand, a *flexible* schedule involves enough possibilities for schedule changes so that deviations in the operating environment can be recovered efficiently. For example it is possible to swap crew or aircraft, or use a reserve crew to recover from a delay.

Stability can often be increased with a low cost, for example by replacing buffer selectively in places that are at risk of being subject to disruptions. A higher stability or flexibility can be achieved by increased cost for example with additional crews and aircraft. In this study we focus on actions to increase stability with low cost since these are generally desirable and worth of realizing.

The consideration of disruption management or robustness is subject of publications since late 1990s when a fast growth of air traffic caused increased congestion. Mercier et al. (2005) propose an integrated aircraft routing and crew scheduling problem incorporating a robustness measure. For the robustness measure the available ground time for crews during an aircraft change is considered. Weide et al. (2007) propose to solve the integrated aircraft routing and crew scheduling model heuristically by solving aircraft routing and

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crew scheduling problems iteratively using a shared objective function. A non-robustness measure is used to penalize *restricted aircraft changes* according to the amount of slack time during such an aircraft change. When a disruption occurs, a low-cost solution for an airline is to swap two crews. Thus, Shebalov and Klabjan (2006) consider task swaps as a recovery option. This means that a crew whose arrival is delayed next flies a flight with a later departure time than its originally assigned flight. The approach of Yen and Birge (2006) also uses information about probability distributions of delays to create robust crew schedules considering delay propagation. However, it considers interdependencies of pairings by modeling the pairing selection problem as a two-stage stochastic programming problem. Schaefer et al. (2005) propose a stochastic extension to the deterministic crew scheduling problem.

In this contribution we aim to improve stability of aircraft routing and crew scheduling. We formulate a stochastic integrated crew scheduling and aircraft routing model. This model involves propagation of delays through aircraft as well as crew through an integrated recourse function. We assume that the formulated model is hard to solve, because already less complex models proposed in literature are hard to solve. Therefore, we propose several changes leading to a more tractable model for robust aircraft routing and crew scheduling.

The new model can be solved by a combination of the iterative approach, proposed by Weide et al. (2007), and classical column generation methods, thus providing a good starting point for considering robustness with real-life problem instances. In contrast to Schaefer et al. (2005) and Weide et al. (2007) the proposed robustness measure considers more interdependencies between aircraft routings and crew pairings without adding significantly more complexity to the problem. In comparison to Yen and Birge (2006) the proposed robustness measure is less exact, but the resulting model also less hard to solve.

We present first numerical results for the recourse model for crew scheduling with data from a European major Airline. We show that already with relatively low penalty values the on-time performance can be increased significantly without increasing the crew costs at all. We assume further increase of the on time performance without additional crew cost, when using the iterative method.

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