Improving airline operational performance through schedule perturbation

Andrew J. Schaefer · George L. Nemhauser

Published online: 24 May 2006
© Springer Science + Business Media, LLC 2006

Abstract Schedule development is typically the first phase of the airline planning process. We present a framework for perturbing scheduled departure and arrival times after a crew schedule has been found. We characterize perturbations that keep a schedule legal while not increasing the planned cost of the crew schedule. We show that when random delays occur in operations, the expected cost can be reduced and the on-time performance improved. Computational results are reported for two real fleets and a large number of crew schedules.

Keywords Airline crew scheduling · Uncertain operations · Schedule development · Integer programming

AMS Classification: 90B06

Airlines operate under uncertain conditions. Weather, congestion, and mechanical breakdowns are examples of why flights may not operate as planned. The operational performance of airlines is becoming worse. In the United States, one flight in four is delayed during the summer, and air traffic is expected to double by 2015 (Anonymous, 2001). At large airports, nearly half of all flights are delayed (Anonymous, 2001). On-time statistics are of great importance to airlines. The Bureau of Transportation Statistics (BTS, 1998) defines a flight to be on-time if it arrives no later than 15 minutes after its scheduled arrival time and publishes rankings of airline on-time performance. These ratings can be used for marketing purposes and a good on-time performance may lead to greater customer satisfaction.

Airline schedules can affect their own on-time performance. In the airline planning process, the first step is schedule development. During the schedule development phase an airline determines when and where it will fly. It also determines the scheduled block time of each flight, that is, the planned duration of each flight, or leg. For the same origin and destination
this time can vary between airlines. It can also vary by time of day for a given airline. For instance, an airline might allocate a greater block time to a flight that departs or arrives during the busiest part of the day.

Schedule development typically takes place at least one year before a flight departs. After schedule development, the airline solves the fleet assignment problem, which assigns each leg to a fleet, or different aircraft type. The routing problem determines the sequence in which each plane will fly legs. After these problems have been solved the crew scheduling problem determines a set of crew trips, or pairings, that partition the set of legs to be flown.

Traditionally, these problems have been considered sequentially, with little or no feedback from later stages to earlier stages. However, some work has been done on integrating the various stages of airline planning. Lohatepanont and Barnhart (2004) integrate schedule development and fleet assignment to increase the number of flights that may be flown. Klabjan et al. (2002) combine crew scheduling and routing with time windows to increase the number of feasible pairings, thus reducing the planned cost of the resulting crew schedule. Rexing, Barnhart and Krishnamurthy (2000) propose a fleeting model with time windows. Cohn and Barnhart (2003) incorporate maintenance considerations into crew scheduling.

Since on-time performance is defined relative to scheduled block time, an airline can improve its on-time performance by increasing the scheduled block times of legs. However, the planned flying time of a crew schedule is a lower bound on its planned cost, which is in turn a lower bound on its operational cost (Schaefer et al., 2004). Crew costs are second only to fuel costs for airlines, and increasing the planned flying time could cause crew costs to increase. This paper introduces a method for determining schedule perturbations that improve on-time performance without increasing crew costs.

We propose a new approach that perturbs the original flight schedule to improve the operational performance of a given crew schedule. The perturbation is made in such a way that the crew schedule and the routing remain feasible. We show that such a perturbation will lead to a performance in operations which, under certain conditions, is likely to be better than, and is at least as good as, the performance of the crew schedule under the original schedule. Our computational experiments indicate that a crew schedule can have a noticeable improvement in operational cost and on-time percentage with the perturbed flight schedule.

In Section 1 we review how pairing feasibility and costs are determined. This description is needed in Section 2 where we discuss schedule perturbations. The effect of schedule perturbation in airline operations is considered in Section 3. We provide computational results in Section 4 and give conclusions in Section 5.

1. Feasibility and crew pairing costs

Because a pilot typically may fly only one fleet, the crew scheduling problem is separable by fleet. A crew flies a set of consecutive flight legs, called a duty, that follow certain regulations and contractual restrictions. The time between two consecutive legs within a duty, or sit time, must be at least a minimum amount if a crew changes planes. The elapsed time of a duty is the number of minutes the duty lasts, including a briefing period before the first leg and a debriefing period after the last leg.

A pairing, or crew trip, is a sequence of duties, each separated by a rest period which must exceed a minimum length. The time away from base (TAFB) of a pairing is the number of minutes from the beginning to the end of the pairing. Pairings flown within the U.S. must adhere to both FAA and contractual rules. For instance, to prevent crew fatigue the “8-in-24” rule requires compensatory rest for a crew that is scheduled to fly more than 8 hours within