Available online at www.sciencedirect.com
ScienceDirect
European Journal of Operational Research 185 (2008) 825–848
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

O.R. Applications

An integrated decision support tool for airlines schedule recovery during irregular operations

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Received 28 June 2004; accepted 15 December 2006
Available online 30 January 2007

Abstract

This paper presents a decision support tool for airlines schedule recovery during irregular operations. The tool provides airlines control centers with the capability to develop a proactive schedule recovery plan that integrates all flight resources. A rolling horizon modeling framework, which integrates a schedule simulation model and a resource assignment optimization model, is adopted for this tool. The schedule simulation model projects the list of disrupted flights in the system as function of the severity of anticipated disruptions. The optimization model examines possible resource swapping and flight re-quoting to generate an efficient schedule recovery plan that minimizes flight delays and cancellations. A detailed example that illustrates the application of the tool to recover the schedule of a major US air-carrier during a hypothetical ground delay program scenario is presented. The results of several experiments that illustrates overall model performance in terms of solution quality and computation experience are also given.
Published by Elsevier B.V.

Keywords: Irregular operations management; Airlines scheduling; Ground delay programs; Simulation and optimization

1. Background

On-time performance of airlines schedule is key factor in maintaining satisfaction of current customers and attracting new ones. However, airlines planned schedules are often subjected to numerous sources of irregularity. In particular, weather accounts for the most part of recorded flight delays (Ageeva, 2000). When adverse weather conditions are anticipated at one airport, the aviation authority (e.g., the Federal Aviation Administration (FAA) in the US) issues a Ground Delay Program (GDP) at this airport. The purpose of this GDP is to increase the time gap between successive flight landings in order to ensure safe operations during the adverse weather period. Under most GDPs, the available number of slots for flight landings becomes less than what is required for the original planned schedule

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0377-2217/$ - see front matter Published by Elsevier B.V.
doi:10.1016/j.ejor.2006.12.045

(Ball et al., 2000; Abdelghany et al., 2004c). Therefore, a scheduled flight could be held at its origin, diverted to a nearby airport, or in the worst case it could be canceled. These disruptions in the planned schedule impact availability of crews and aircrafts for future flights. For instance, when a flight is delayed, its crewmembers may misconnect their next scheduled flights. They may also exceed the limits for legal duty periods; resulting in not completing remaining flights in their planned schedules. Hence, one flight delay could have a cascading downline disrupting impact over time and space unless appropriate recovery actions are taken.

For a small airlines network, tracking and efficiently recovering the downline impact of few delayed flights could be a simple task. However, for major airlines with more than 2000 daily flights, if GDP programs are issued at one or more airports, tracking and recovering the downline impact of these GDPs could be extremely challenging and time consuming (Monroe and Chu, 1995). Consequently, considerable attention has been given to develop decision support tools to limit flight delays associated with GDPs for major commercial airlines. A recent comprehensive review of concepts and models used to develop these tools can be found in Clausen et al. (submitted for publication). For instance, Teodorovic and Guberinic (1984), Teodorovic and Stojkovic (1990), Jarrah et al. (1993), Talluri (1996), Yan and Yang (1996), Yan and Young (1996), Cao and Kanfani (1997a,b), Argüello and Bard (1997a,b), Thengvall et al. (2000, 2003) and Rosenberger et al. (2003) describe different recovery models with the decision variables are describing aircraft rerouting plans in order to improve overall system performance during irregular operations. Similarly, Clarke (1997), Wei et al. (1997), Lettovsky et al. (1998), Stojkovic and Soumis (1998), and Abdelghany et al. (2004a) describe crew-oriented recovery models. One drawback of these models is that they consider only one resource type. In other words, they ignore evaluating the impact of recovery actions generated for one resource on other unconsidered resources. For example, when a decision is made to delay a flight because of the unavailability of its aircraft, investigating the impact of this delay on crew duty period is ignored. Up to the authors' knowledge, the problem of developing an integrated decision support tool that simultaneously recovers multiple resources is not thoroughly considered in the literature.

This paper presents an integrated Decision Support Tool for Airlines schedule Recovery during irregular operations, DSTAR. The tool allows operators in the airlines control center to detect current and future flight delays and to generate proactive integrated recovery plan to avoid these delays. DSTAR implements a greedy optimization approach in a rolling horizon framework. The framework integrates a schedule simulation model and a resource assignment optimization model. The schedule simulation model predicts the list of disrupted flights in the system as function of resources availability and applied legality rules. The optimization model seeks to find the optimal plan of crew and aircraft swapping, reserve utilization and flight re-quoting to recover the projected list of disrupted flights. The main contributions of this tool are as follows. First, it integrates recovery decisions for multiple heterogeneous airline resources (aircraft, pilots, and flight attendants) with different scheduling constraints. Second, the tool provides proactive recovery plans for schedule disruption management, so it recovers flights with anticipated resource problems prior to its departure time. Finally, the tool enables near real-time response. As presented hereafter, efficient recovery plans for severe schedule disruptions are generated in less than 1 minute.

The paper is organized as follows. A description of resource possible operation violations during irregular operation conditions is presented in Section 2. Section 3 illustrates interdependency among airline resources and the concept of slack time. Current practice in airlines operation management and schedule recovery is described in Section 4. Section 5 formally describes the airlines recovery problem. The overall framework of DSTAR is presented in Section 6, which also describes the mathematical formulation of the integrated recovery problem. A detailed illustrative example is presented in Section 7. The application of DSTAR on the schedule of a major US airline is presented in Section 8. The model computation experience and solution quality are presented in Section 9. Finally, conclusions are presented in Section 10.

2. Resource violations during irregular operations

Crew schedules are typically designed in what is known as trippairs. A trippair is a workload assignment for each pilot and flight attendant. The length