Airline Scheduling: Planning for Robust Operations

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1 The Airline Schedule Planning Process

Airline schedule planning is concerned with generating a schedule that has the most revenue potential and resolves a host of related issues involving fleet assignment, aircraft maintenance routing and crew scheduling. Airline schedule planning has been extensively studied in the past decade and numerous models and algorithmic approaches have been developed. For a recent review, see Cohn and Barnhart (2003).

Many of the research accomplishments pertaining to airline schedule planning have been applied in the airline industry and have improved airlines' performances. This notwithstanding, almost all optimization models in this area have assumed that flights, crews, and passengers will operate as planned. Thus, airlines typically construct plans that maximize revenue or minimize cost based on the assumption that every flight leg departs and arrives as planned. Because this optimistic scenario rarely occurs, these plans are frequently disrupted and airlines often incur significant costs in addition to the originally planned cost. Currently, the *optimal* planned schedules generated by schedule planning systems are far from *optimal* in operations. It is estimated that the financial impact of irregularities on the daily operations of a single major U.S. domestic carrier may exceed $440 million per annum in lost revenue, crew overtime pay, and passenger hospitality costs (Clarke and Smith 1999). The cost of delays and disruptions is not only significant, but also rapidly increasing. The Air Transport Association estimates that delays cost consumers and airlines about $5.2 billion in 1999 and $6.5 billion in 2000. (Air Transport Association website

2003).

2 Delays, Cancellations and Disruptions

There are many reasons for flight delays and cancellations, including severe weather conditions, unexpected aircraft and personnel failures, and congestion at the airport and in the airspace. In the year 2000, about 30% of the flights were delayed, and about 3.5% of the flights were cancelled. Because schedule planning systems do not attempt to manage possible delays and cancellations, the delays and cancellations cause disruptions to airline schedules that are often extremely difficult to repair and recover, sometimes with significant negative effects.

Flight delays and cancellations not only lead to aircraft and crew schedule disruptions but also cause passengers to be disrupted from their original itinerary. Passengers are disrupted if their planned itineraries become infeasible because one or more of the flights in their planned itineraries are cancelled or there is insufficient time to connect between flights. In 2000, it is estimated that about 4% of passengers were disrupted, among which about half are connecting passengers (Bratu and Barnhart 2002). The impacts of passenger disruptions are tremendous (Bratu and Barnhart (2002). First, disrupted passengers incur very long delays: in one case study, the average delay for disrupted passengers is estimated to be about 419 minutes, while the average delay for non-disrupted passengers is 14 minutes. Second, passenger disruptions cause huge direct revenue losses. Associated revenue losses include delay costs for passengers, airline revenue loss due to passengers being served by other airlines, and overnight passenger costs. Third, there are some other significant potential losses, such as loss of goodwill.

In recent years (prior to September 11, 2001), flight delays and cancellations increased significantly in the U.S. In 2000, 30% of the flights were delayed, a 100% increase compared to 1995, and about 140,000 flights were cancelled, a 500% increase compared to 1995 (Bratu and Barnhart 2002). As staggering as these numbers are, it is estimated that flight delays and cancellations might increase dramatically in the future: air traffic in the US is expected to double in the next 10-15 years, and each 1% increase in air traffic will bring about a 5% increase in delays (MIT Global Industry Program 2003 and Schaefer et al. 2001). This will lead to more frequent and serious schedule disruptions and tremendous revenue loss, unless airline schedule planning and operations are significantly improved. This has motivated our research in *airline schedule planning for robust operations*.

3 Models and Algorithms

In this paper, we present several new airline schedule planning models, and their associated algorithms, to achieve robust operations. Our approaches are summarized as follows:

We develop an approach to determine aircraft maintenance routes that minimize propagation of delay in the airline network, and reduce disruptions and delays to passengers. This approach creates aircraft routes with slack appropriately placed to mitigate the impacts of delayed aircraft, that is, to reduce passenger delays and misconnections.

We develop an approach to re-time flights and minimize the expected number of disrupted passengers. Through schedule re-timings on the order of 5 to 10 minutes, slack is judiciously re-allocated, and again passenger delays are minimized and misconnections are reduced significantly.

We integrate the above approaches to re-route aircraft and re-time flights and determine the impact of simultaneous routing and scheduling decisions. We compare the amount of delay propagated in the airline network, the total minutes of passenger delays, and the number of passengers disrupted in our solution compared to solutions generated using conventional approaches.

We present models to generate crew pairings that allow for more robust crew operations, given pre-determined aircraft fleet assignments and routings. We use proxies for robustness, including the number of *tight* crew connections and the number of times crews must transfer between aircraft. We couple this approach with our approaches described above to build robust maintenance routes. Simultaneously crew and routing solutions allow us achieve minimal (or near-minimal) crew costs, while maximizing robustness in the crew and aircraft operations.

We develop a model and solution algorithm for fleet assignment designed to facilitate recovery operations. As an example, we determine optimal (or near-optimal) fleeting solutions with the minimum number of aircraft types assigned to flights at spoke stations containing only a limited number of flights daily.

We investigate the value of our robust planning approaches using data provided by a major U.S. airline. We show that compared to solutions generated using conventional approaches, our robust planning approaches can reduce delays and aircraft and crew passenger disruptions, with only small increases in planned costs.

References

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