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A flight scheduling model for Taiwan airlines under market competitions

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Abstract

In this research, we develop a short-term flight scheduling model with variable market shares in order to help a Taiwan airline to solve for better fleet routes and flight schedules in today's competitive markets. The model is formulated as a non-linear mixed integer program, characterized as an NP-hard problem, which is more difficult to solve than the traditional fixed market share flight scheduling problems, often formulated as integer/mixed integer linear programs. We develop a heuristic method to efficiently solve the model. The test results, mainly using the data from a major Taiwan airline's operations, show the good performance of the model and the solution algorithm.

Keywords: Scheduling; Routing; Optimization; Variable market shares; Non-linear mixed integer program

1. Introduction

Fleet routing and flight scheduling are essential to a carrier's profitability, its level of service, its competitive capability, and its market share. There are many factors that need to be considered in past airline fleet routing and flight scheduling. These factors generally include the seasonal passenger trip demands, the passenger ticket price, the operating constraints (e.g. the aircraft type, the fleet size, the available slots, the airport quota), the operating costs, as well as the aircraft maintenance and crew scheduling [1]. Most past research has used fixed parameters, including the projected market share (and demand), for flight scheduling and for fleet routing. However, market share may vary, especially in competitive markets. It is dependent on the supply (e.g. the flight frequency, the trip travel time, the safety and equipment, the fare, the crew and staff service) of the carrier and its competitors, as well as the passenger characteristics.

In practice, passenger choices of airline and flight are not only affected by the ticket price, but also the safety standards, and the level of service, the frequency of flights and the timetable. A carrier should not neglect the influence of its timetable on its market share. For example, the passenger demand could be lost or vary with respect to the projected demand if the timetable is inferior. On the other hand, a good timetable that takes into consideration passenger reactions to its services will attract more passengers and will improve the carrier's market share in actual operations. Therefore, to set a good flight schedule, not only does the fleet and related supply have to be considered, but also variable market shares in a competitive market have to be taken into account.

Currently most airlines in Taiwan use a trial-and-error process for fleet routing and flight scheduling. The flight scheduling process typically consists of two separate phases: (a) the market share/demand projection phase and (b) the schedule construction and evaluation phase. There are

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only four airlines with domestic operations and each airline's services for the upcoming season are designed to resemble the preceding corresponding period. In practice, the target airline can usually estimate the competitors' services for the next season. Therefore, in the first phase, planners from the marketing department estimate the market share and passenger demand for the next season based on the projected future market demand, as well as its and its competitors' current and past operational data, including market share, passenger demand, timetable and other services. Note that in the first phase competitor timetables for the next season also can be projected to help to estimate the market share. The draft timetable is then sent to the scheduling department for the designing of fleet routes. In the second phase the timetable is finalized. In particular, the drafted timetable is adjusted according to fleet routes, fleet size, fleet availability, related costs/revenue, crew scheduling, and maintenance arrangements. This process is iterated manually until a desirable timetable and fleet routes are obtained.

Since the flight scheduling and fleet routing in the second phase are neither efficient nor effective, Yan and Young [2] developed a set of network models to help carriers effectively solve for short term flight schedules and fleet routes based on a draft timetable and all the operating constraints. Their models should be more systematic and efficient than the traditional trial-and-error method. To improve Yan and Young's model, Yan and Tseng [1] incorporated the two phases into a single framework. They developed an integrated scheduling model for multi-fleet routing and flight scheduling, with the objective of maximizing the system profit, given a fixed projected market share (and demand) and all the operating constraints.

In addition to Yan and Young's [2] and Yan and Tseng's [1] work, much other research has been devoted to fleet routing and flight scheduling problems, by the air industry as well as in academic fields. For example, Levin [3] used bipartite graph, time-space network, and arc-chain techniques for modeling fleet routing problem. Abara [4] developed an integer linear programming model for fleet assignment with fixed flight departure times and formulated it as a multi-commodity network flow problem. Hane et al. [5] modified Abara's model so they could solve daily aircraft routing and scheduling problems (DARSP) without departure time windows. Clarke et al. [6], based on Hane et al.'s basic model, tried to develop a fleet assignment model which would take maintenance and crew scheduling into considerations. Desaulniers et al. [7] proposed two integer programming models, a set partitioning type model and a time constrained multicommodity network flow model, for solving DARSPs according to a set of operational flight legs with known departure time windows. However, in all of the aforementioned models, including Yan and Tseng [1] and Yan and Young [2], to finalize the timetable and schedule, the assumed market shares are fixed, and the variation of market shares due to market competitions is neglected. As a result, the schedules and fleet routes offered may not reflect the actual market share, but be inclined to be inaccurate and inefficient in actual operations, and might possibly decrease the system performance.

As mentioned above, in past airline scheduling models, the market share and the projected demand for a specific OD pair, for a given time interval for the target airline are assumed to be fixed. Passenger choice behaviors are neglected. Based on these fixed market share models, one might wonder if traditional sensitivity analysis techniques would actually be useful for understanding the influence of the variable demands on the solution. However, in this research, the evaluation of the target airline's market share, for each OD pair, for each time interval, is complicated, and is correlated with passenger choice behaviors, which are in turn related to such factors as the choice of airline, the fare, the flight frequency and the market characteristics. Moreover, when the related supply is changed, simultaneous changes in market share, for all OD pairs for all time intervals, become more complicated. Therefore, it becomes very difficult for an airline to forecast marker share by performing a sensitivity analysis based on an existing fixed market share model. That is, when developing a flight scheduling model with variable market shares, it is necessary to consider the passenger choice behavior.

Apart from focusing on airline fleet routing and flight scheduling, there has been research applying multinomial logit models to formulate passenger choice behaviors in competitive market situations. These models usually take into account such factors, as the quality of service, the safety record, the flight frequency, the travel time, the fare and the passenger's attributes, to estimate the airline market share. For example, see [8–12]. Proussaloglou and Koppelman [13] have discussed the effect of the Frequent Flyer program (FFP) and travel purpose on the passenger choice behavior. They found that these two factors had an influence on passenger choice. Proussaloglou and Koppelman [14] developed a joint choice model that took into account the aircraft's capacity constraint, to repeatedly estimate airline market share. Duann and Lu [15] discussed the joint choice decision problem (airline choice and flight choice) of Taiwan air passengers on non-stop flight operations to try to find the factors that had a significant effect on their choice decisions. The results showed that the variables which most significantly influenced the choice of Taiwan passengers as to airline flight selection, included such factors as safety and equipment, crew and staff services, early/late flight arrival times, flight delays, the fare, in-flight food and drink services, and passengers inertia. Yan [16] further modified Duann and Lu's model by incorporating the attribute of travel time into the model for the operations of non-stop and one-stop flights. From the above literature review we see that passenger choice behaviors vary with different market characteristics, meaning that when we incorporate passenger choice behaviors into a flight scheduling model, the passenger choice model and other related factors should reflect the carrier's own market condition.