Market-Oriented Airline Service Design

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Summary. The decision of an airline about its service offering is a challenging task as it involves various decisions at the interface of operations and marketing: which origin-destination (OD) markets to serve, over which routes, and at which departure times (schedule design), at which price and other ticket conditions (pricing/fare product design), and what aircraft type to assign to each of these flights (fleet assignment). These decisions are highly interdependent with regard to their profit impact: on the one hand, the fleeted schedule fixes a large part of the cost; on the other hand, schedule, price and fare conditions are the most important factors influencing passenger's choice and thus revenue. While schedule- and fare-related decisions are often treated in isolation in airline planning, profit maximizing service design should encompass the simultaneous determination of all features in the service package that drive profit. We develop a market-oriented model for airline network service design integrating flight schedule design, fleet assignment and pricing. Under suitable assumptions, the model is a mixed-binary problem with concave objective function and linear constrained that can be solved exactly by standard techniques. The optimal solution obtained at the strategic level can be used as input for operational revenue management models providing an interface for hierarchical decision making.

1 Introduction

Profit-oriented airline service design involves many interdependent decisions at the interface of operations and marketing, in particular schedule planning and pricing, defining to a large extend the ultimate product of an airline from the customer's point of view. Due to complexity and problem size, airlines usually treat schedule- and marketing-related decisions in isolation and further decompose the whole schedule planning process into a set of four core problems that are solved sequentially: schedule design, fleet assignment, maintenance routing, and crew scheduling [2], [7], [10]. Even these smaller core problems present significant modeling and optimization challenges and for most of the airlines schedule design is still a manual process due to complexity and finally to unaccounted marketing requirements in existing models.

From a market-oriented perspective it would be desirable to simultaneously determine schedule- and fare-related criteria driving profit. This integration is not only motivated by the quest for global optimization but also because 1.) recent advances in forecasting demand and modeling choice behavior at the itinerary/fare class level allow such integration for real-world applications, 2.) contrary to expectations, integrating pricing into schedule design decisions does not necessarily come along with an increase in computational complexity, and finally 3.) a direct interface to revenue management models is established. Before we turn to the development of the integrated model, we first review the relevant literature in the area of schedule design/fleet assignment, pricing and demand modeling.

Schedule Design. While the literature on fleet assignment is vast and decision support tools for fleeting are common [8], there are only a few articles on schedule design optimization. Approaches to profit-oriented schedule design or iterative schedule design/fleet assignment are described in, for example, [5] and [12], and for a survey [6]. More recently and most relevant to our approach, [9] developed a mixed integer linear program for integrated schedule design and fleet assignment (ISD-FAM) with the objective to maximize schedule profitability based on an incremental approach. To account for recapture and network effects caused by schedule modifications, unconstrained itinerary-specific average demand for an initial schedule is adjusted by approximate demand correction terms. Demand is not modeled as a closed-form function depending on the controls but instead selected values are estimated with a schedule evaluation model and updated iteratively as needed when the schedule has significantly changed during the optimization. Prices are predetermined and enter the model as mean itinerary fare values averaged across booking classes. The assumption of fixed prices is common in schedule design models with the exception of [5]. They propose a nonlinear model and a heuristic for the simultaneous determination of profit-maximizing flight schedules and itinerary prices in a hub-and-spoke network. Demand is incorporated as a multinomial logit function influenced by price and schedule preference. There is only one size of aircraft and thus no fleet assignment.

Pricing. On the other hand, there are numerous approaches in the literature for pricing airline services given a fleeted schedule [13]. For the purpose of integrating pricing with schedule design, we are interested in more strategic network pricing models and therefore focus on the deterministic multi-product multi-resource case. A suitable standard model is given in [13], ch. 5.4.1, that can be considered as a special case of our integrated approach when all fleet assignment decisions are fixed.

Demand. Pricing models assume that the decision maker has information about the price-demand relationship in terms of a suitable multi-product demand function (see [13], ch. 7.3.3). Today, both practitioners and researchers are aware of the need to account for customer behavior in traditionally operations-driven airline planning problems likewise. Discrete choice models, especially the Multinomial Logit (MNL) model, have been applied for a long