Airline Scheduling:
Demand-Supply Interactions and Robustness

Thesis Summary

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Scheduling is one of the most important activities in airlines, as it affects profitability and competitive positioning of the airline. Scheduling in airlines is divided into various stages, because of the scale and complexity of airline problems. We work on three scheduling stages in this thesis. These stages are schedule design, fleet assignment and routing. While schedule design decides the itineraries to offer along with the corresponding departure and arrival airport and departure and arrival time; fleet assignment decides the aircraft type to be assigned to each flight. An itinerary is defined, in airline literature, as a specific sequence of flights legs in a market (an ordered origin-destination pair), in which first leg originates from the origin airport at a particular time and final leg terminates at the final destination airport at a later time. Routing decides the path followed by an aircraft during the planning horizon, while taking care of various aircraft maintenance restriction.

In this thesis, we focus on the formulation and solution of problems that can incorporate some important interactions to improve the performance of scheduling models. The two problems addressed in this thesis are:

(*i*) Demand-Supply Interactions in Schedule Design and Fleet Assignment

(*ii*) Robustness in Routing

Proper understanding of basic concepts related to demand and their integration with scheduling models helps in attracting more and profitable passengers. Incorporating robustness helps in improving the delivery of service to those passengers.

Demand is one of the most important aspects for schedule design and fleet assignment stages of airline scheduling. Both these stages try to serve the demand and match the supply with demand as close as possible. These stages require demand estimates for making decisions, but it has also been demonstrated that demand for an itinerary is a function of savailabilityy of itineraries, itineraries attributes and capacity offered by the airline in the market. So, while deciding about which itineraries to offer, the demand for an itinerary should be considered as a function of all the itineraries being offered in the market. However, most of the literature assumes itinerary demand as an input parameter. There has been very less work on capturing demand as a variable of scheduling models. We develop a model to incorporate following two facets of demand-supply interactions -

a). To formulate the itinerary demand as a function of availability and attributes of all itineraries in the market, while deciding the itineraries to offer in market

b). Demand carried by a flight is constrained by the capacity of aircraft type assigned to the flight and if the demand for a flight is more than capacity, some customers would have to be denied service on their desired itinerary. The airline would try to capture these customers on other itineraries of the airline rather than losing those to competitors.

We incorporate both these interactions in our model. Though there have been some work in literature on these interactions; we provide an alternative approach that overcomes many gaps that exist. Our method helps in reducing the subjectivity and convergence issues of existing approaches. We also formulate demand as a variable of the model, as compared to the approaches in literature that consider demand as a parameter and use iterative approach to update demand estimates and match supply with demand. So, in our model the demand for itineraries can be different for different candidate solutions of the problem. We calculate the total flight demand as the sum of demand for all itineraries, in which flight is one of the legs. In case of a denied service, we use recapture-rate (a measure of attractiveness of one itinerary with respect to another itinerary) to determine the potential number of passengers that can be captured back by airline's other itineraries, provided the capacity is available on those itineraries. We use logit-based demand modeling in these scheduling problems. We derive a variant of one of the existing demand models and use the resultant model as a functional form in our scheduling model. The reason is that logit-based models have been empirically shown to perform better than few other existing models. We provide a new approach for handling the interactions, discussed in *b*) above. Existing models in literature assume the customers to get redirected to alternative itineraries (in case of a spill), that are optimal for airline. Our approach takes into consideration that customers try to maximize their utility, while selecting alternative itinerary. Our model is a non-linear model, where non-linearity lies in the class of fractional programming. We use transformations, given in literature, to convert the non-linear model to a linear mixed integer programming model. We illustrate the utility of our model with the help of different examples.

We discuss the application of our model, capturing these demand-supply interactions, in case of a code-sharing agreement between airlines. Code-sharing refers to an alliance between two or more airlines, that agree to share services on some of the fights. Such alliances can have different types. We consider the issues related to the design of combined schedule design (flight offerings) by the participating airlines. We discuss how our model can be adapted to the problem in case of code-sharing.

The next problem addressed in this thesis is that of incorporating robustness in scheduling. We develop a multi-objective model to incorporate robustness in routing. We provide a dynamic modeling for one of the robustness metric, considered as a static in literature. We also study the trade-offs between robustness and profitability objectives using two solution approaches - Fuzzy Mathematical Programming based Max-Min Approach and Genetic Algorithms (GA). Fuzzy Mathematical Programming approach provides a non-dominated solution and GA is used to study the trade-off between robustness and profitability. We illustrate that incorporating robustness in routing can help in taking care of uncertainty (in terms of delays, cancellations etc.) during implementation of schedule.