AIRLINE PLANNING CONSIDERING COMPETITION EFFECTS

LUIS CADARSO, ÁNGEL MARÍN
Universidad Politécnica de Madrid
E.T.S.I. Aeronáuticos, Pza. Cardenal Cisneros, 3 Madrid 28040, Spain.
luis.cadarso@upm.es, angel.marin@upm.es,

Abstract

The airline schedule design and fleet assignment problems consist of determining flight departure times and the assigned fleet type. They are usually solved sequentially without accounting for market competition. We propose a new integrated approach to design flight legs accounting for fleet assignment and market competition, providing robust itineraries for connecting passengers. An application of the model for a simplified IBERIA network is shown.

1. Introduction

In order to produce operational schedules, airlines engage in a complex decision-making process, referred to as airline schedule planning. The profitability of every schedule does not only depend in one unique airline. It will depend on every airline in the market. Thus, market competition must be introduced.

Lohatepanont and Barnhart (2004) select flight legs to include in the flight schedule and simultaneously optimize aircraft assignments to these flight legs. Lan et al. (2006) consider passengers who miss their flight legs due to insufficient connection time. They minimize passenger misconnections by retiming the departure times of flight legs within a small time window.

Despite the continuing interest in frequency competition based on the S-curve phenomenon, literature on the game theoretic aspects of such competition is limited. Hansen (1990) analyzed frequency competition in a hub-dominated environment using a strategic form game model. Dobson and Lederer (1993) modeled schedule and fare competition as a strategic form game. Adler (2001) used an extensive form game model to analyze airlines competing on fare, frequency and aircraft sizes. Each of these three studies adopted a successive optimizations approach to solve for a Nash equilibrium.

2. Problem Description

The problem consists of solving the schedule design and the fleet assignment in an integrated way. Passenger unconstrained demand in each market *w* (d_w) is known. Depending in the offered frequencies by the airline and its competitors the market share (ms_w) for each market is determined. Passenger demand is assigned to different itineraries *i* attending market *w* departing during time period *t*. Passengers are represented by $h_{i,t}^{w}$.

$$\sum_{i \in I_w} \sum_{t \in T_w} h_{i,t}^{w} \leq ms_w d_w \quad \forall w \in W$$

Market share (ms_w) can be modeled according to the so-called S-curve or sigmoidal relationship between the market share and frequency share, which is a widely accepted notion in the airline industry.

$$ms_w = \frac{\left(\sum_{i,t \in I_w,T} f_{i,t}\right)^{\alpha}}{\left(\sum_{i,t \in I_w,T} f_{i,t}\right)^{\alpha} + \left(f_{eff}\right)^{\alpha}}$$

, where $f_{i,t}$ denotes whether itinerary *i* departing during time period *t* is flown, f_{eff} is the effective frequency of the competing airlines and α is the frequency elasticity.

Robustness is introduced avoiding misconnected passengers. Assigning a statistical distribution to misconnected passengers, the probability of getting misconnected passengers depending on connection time can be calculated. Airports capacities are included. We only limit slot availability at congested airports in the network. For a departing flight leg *s* during time period *t* with fleet type *p* ($z_{s,t}^{p}$), an available slot must exist, $\overline{qd}_{k,t}$.

$$\sum_{s \in DS_k} \sum_{p \in P} z_{s,t}^{p} \leq \overline{qd}_{k,t} \quad \forall k \in K, t \in T$$

The fleet size will determine the flight legs that may be performed in the planning period, and consequently, the attended demand. The schedule will be periodic, that is, the schedule will repeat after the planning period ends. A minimum separation time between consecutive flight legs is imposed in order to avoid competence within the airline.

3. Computational Experiments

As a proof of the model we have done some computational experience. We have implemented a simplified version of IBERIAS's air network (Figure 2): the Spanish network. It is a pure *hub-and-spoke* network with 23 different airports. There are three different fleet types available for this study case.

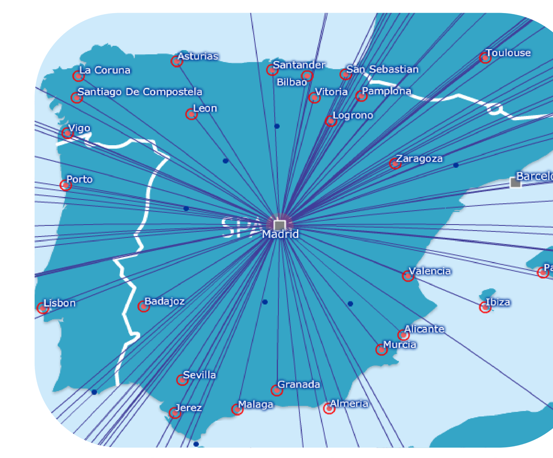

Figure 2: Air network

The planning period we have considered is of 24 hours. We require to the planning to be periodic, that is, the fleet distribution must be equal at the beginning and the ending of the planning period.

Binary Variables	11,661
Continouos	646844
Constraints	46,255
Non-zeroes	1,502,479

Table 1: Model size

The model size for this study case is shown in Table 1. In this case time has been discretized into periods of 15 minutes. We have considered every potential flight leg between each spoke and the hub.

We have used GAMS/Cplex 11.1 to implement our programs.

Origin.Destination	Passengers	Capacity	Market Share (%)
LCG.MAD	348,8	564	50
MAD.LCG	410,99	564	50
SCQ.MAD	43,27	141	20
MAD.SCQ	135,02	141	20
OVD.MAD	251,73	735	60
MAD.OVD	597,69	735	60
BIO.MAD	1051,74	1223	62,3
MAD.BIO	1066,92	1223	62,3
BCN.MAD	4163,46	4341	79,4
MAD.BCN	4316,14	4341	79,4
PMI.MAD	1709,26	1741	64,6
MAD.PMI	1732,72	1741	64,6
IBZ.MAD	703,35	823	60
MAD.IBZ	823	823	60

Table 2: Passenger flows and capacities

Airport	A-319	A-320	A-321
LCG	1	-	-
SCQ	1	-	-
OVD	2	-	-
BIO	1	-	2
BCN	-	-	5
PMI	1	-	3
IBZ	1	-	1
SVQ	2	-	1
VCL	3	-	-
AGP	1	-	1
MAD	2	1	2

Table 3: Fleet distribution

A summary of aggregated passenger flows and provided capacities are shown in Table 2. Some spoke airports are not connected anymore with the hub in the model solution. Table 3 shows fleet distribution at the beginning and the ending of the planning period.

5. Conclusions & Future Research

The proposed model solves airline's timetable development and fleet assignment. The model uses as input data the unconstrained demand for each market. Competition (including airlines and high speed trains) has been introduced in the model in order to represent actual market shares. However, we are only accounting for frequencies. Travel time and fare must also be taken into account.

We need to include capacities from partner airlines. Elastic demand depending on offered frequencies and fares must be taken into account in order to represent the actual attended demand.

6. References

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