Air Transport Network Design for Low-Demand Regions: An Optimization-based Approach

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1 Introduction

The liberalization of air transport was expected to bring about the reduction of flights and/or the increase of fares in regions without sufficient passenger demand to have profitable legs, including remote regions where transport plays a crucial role with respect to the mobility of people and goods. Because of this, governments (aviation authorities) have decided to accompany the liberalization process with the implementation of subsidy schemes [1], such as the Public Service Obligations (PSO) adopted in Europe [2]. In this paper we present a decision approach designed to assist governments in the implementation of a PSO system. The approach is aimed at minimizing the social costs of the air transport network of a low-demand region, being based on an integrated flight scheduling and fleet assignment (IFSFA) model. This type of optimization model is often used by airlines, but with a different objective: the maximization of profits [3,4]. To the best of our knowledge no IFSFA models have been designed for application to subsidized air transport networks. Literature about this topic has, instead, focused on the economic and social impact of such networks in low-demand regions [5,6] and on the legal framework underlying their development [7,8].

2 Decision Approach

A graphic description of the approach to air transport network design proposed is given on Figure 1.

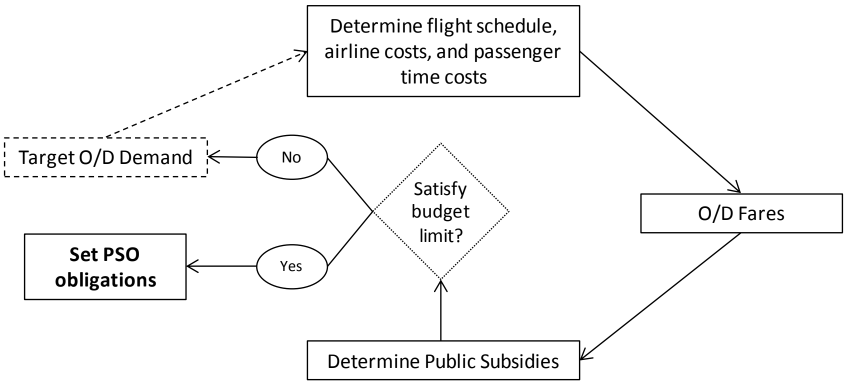

Figure 1 - Overview of decision approach

The first step of the decision approach consists in the definition of the number of passengers per O/D market that need to be served (target O/D demand). This value is used as an input to the integrated flight scheduling and fleet assignment model. The outputs of this model are the optimal flight schedule, airline costs and passenger time costs. Airline costs are the sum of the vehicle costs to operate each flight and the fleet costs of having an aircraft in use but parked on an airport (off-base costs). Passenger time costs are the sum of flight time costs and waiting time costs at intermediate airports. O/D fares are determined next using a demand function in which airfares are the dependent variable and the number of passengers per O/D market to be served under PSO conditions is one of the explanatory variables. After that, public subsidies can be calculated as the difference between the expected revenues made by the airline and the airline costs obtained through the optimization model multiplied by a factor that reflects non-operational costs (not captured by the optimization model). The level of subsidies is then compared with the available budget. If the budget is exceeded the O/D demand should be updated and the process is repeated; otherwise, the government will be able to set the PSO according to the outputs of the optimization model.

3 Model application

The decision approach was applied to a case study involving the air transport network of the Azores (Portugal). The Azores are an archipelago of nine islands located in the Atlantic Ocean about 1,500 km west of Lisbon with a population of around 245,000. Specifically, we compared the network obtained through the decision approach described in the previous section (optimum network) with the performance of the current network. For a typical day of operation of a busy month (September), without limiting the maximum passenger waiting time, the optimum network requires a public subsidy of 63,006 EUR, which is, a 21.0 percent decrease with respect to the current network, and can be operated with only 5 aircraft – 3 DH2 and 2 DH4 – instead of 6 aircraft – 2 DH2 and 4 DH4 (Table 1). Total airfares decrease by 8.3 percent to 68,292 EUR, airline costs decrease 14.9 percent to 65,650 EUR, and passenger time costs decrease 1.3 percent to 9,282 EUR. The number of flights decreases from 42 to 40 and the average load factor increases from 51.9 to 62.1. The percentage of non-stop passengers is 81.6 percent instead of 85.0 percent, the average waiting time decreases to 46.8 minutes (1.7 percent), and the maximum waiting time is 390 minutes instead of 495 minutes for passengers both on 1-stop and 2-stops itineraries. All passengers can travel with a maximum of 2-stops while on the current network seven O/D markets cannot be served with 2-stops in the same day. Table 1 summarizes the main results we have obtained, also for the case in which the maximum passenger waiting time between flight-legs is limited to 3 hours. Overall, results show that the subsidies currently financing the Azores air transport network can be considerably reduced without compromising both passengers' connectivity and airline costs. The reductions are obtained with a generalized decrease in the airline costs (vehicle and off-base costs). Airfares also decrease significantly on average.

Table 1 – Main application results

Alternative	Input Parameters			Main Results													
	Maximum Load Factor	Maximum Waiting Time	Fleet (DH2 + DH4)	Subsidies		Total Cost		Airline Costs		Time Costs		Airfares		Flights	Load Factor	Connecting Passengers	
				Value	Var. %	Value	Var. %	Value	Var. %	Value	Var. %	Value	Var. %			Number	Avg Wait
Current Solution	-	-	2 + 4	79792		86523		77116		9407		74441		42	52%	114	47.7
No waiting time limit	90%	No limit	2 + 3	63008	-21.0	74932	-13.4	65650	-14.9	9282	-1.3	68292	-8.3	40	62%	133	46.8
3-hour waiting time limit	90%	3 hours	3 + 4	68919	-13.6	78701	-9.0	69865	-9.4	8836	-6.1	68811	-7.6	41	62%	130	23.8

4 Conclusion

The approach proposed in this paper is, we believe, a significant contribution to the air transport literature. Indeed, to our best knowledge, there are no optimization-based tools to support the design of the air transport network of low-demand regions taking into account PSO (or other public subsidy schemes). The application of the approach to the Azorean network – fully operated under PSO regulations – clearly shows its usefulness in practice.

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