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An Airline Fleet Planning Method Constraint with Minimal Cost

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Abstract. The fleet planning is to assign the appropriate aircraft to the corresponding routes while meeting the passenger demand, thereby reducing the operating costs of airlines. However, the current fleet planning research does not take the huge costs and improvement plans of regional passenger aircraft operations into account. In this paper, a multi-objective fleet planning model that minimizes prime cost of airlines is firstly established considering passenger distribution on each route, five costs and corresponding constraints. Secondly, the linear weighting method is used to transform the model into a single-target fleet planning model. Finally, based on the real data of a domestic airline, LINGO software is used to solve the model from the perspective of conventional optimization and mainline-regional jet hybrid, and the original scheme of the company is optimized and analyzed respectively. Comparing with the optimization results with the original scheme, it is shown that the multi-objective fleet planning model proposed in this paper has both theoretical and practical significance.

Keywords: Fleet planning; direct operating costs; multi-target optimization;

1. Introduction

In recent years, China's civil aviation traffic has been growing rapidly, but large hub airports are in constant tension, while a large number of regional airports in small and medium-sized cities are deserted. The number of regional aircraft is too small and the fleet configuration is unbalanced, which leads to high operating costs and low transportation efficiency for airlines.

Fleet planning refers to the relationship between the number of aircraft and the composition ratio of different types of aircraft. Dantzig firstly established a simple fleet planning model [1], but his model was just a general integer linear programming model. In recent years, scholars' research on fleet planning has gradually shifted from profit maximization to pollutant emission and cost minimization. Christoph Müller successfully reduced the carbon emissions of two European airlines by establishing a mixed integer linear programming model [2]. Yongha Park decomposed costs into direct operating costs (DOC) and fuel costs, then built a mixed integer linear programming model and solved it [3].

In recent years, Chinese scholars' research on fleet planning has also focused on carbon emissions and cost minimization. Gu Runping first completed a fuel cost-based fleet planning study [4].The disadvantage is that the definition of cost is too narrow. In view of this, Gu extended the cost to fuel cost, unit time cost and fuel cost, unit take-off and landing costs in the research of 2014 [5] and 2016 respectively. Gu's latest research [6] organically combines "cost minimization" and "carbon emission minimization" to establish a model, and conducts a sensitivity analysis [7].

The current fleet planning research calculates various costs of airline and establishes the model with minimal cost. The calculation method of the cost is relatively mature, but the cost consideration may be incomplete. Moreover, the fleet plan does not take into account the huge costs and improvement plans of regional passenger

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aircraft operations [8]. This study provides suggestions for airline fleet configuration from a new perspective of "sub-routes and regional airliners", and improves the utilization of regional routes, thereby reducing airline operating costs and increasing economic benefits.

2. Fleet Planning Model

2.1. Objective Function

Assume that the airline has m routes and n types of aircraft. It is stipulated that x_{ij} is a flight on route j operated by type i .The goal is to minimize the total cost.

a) Fuel costs: $$\min f_1(x)=\sum_{i=1}^{n}\sum_{j=1}^{m} FF_i\cdot FP\cdot t_{ij}\cdot x_{ij}\cdot Freq_j \quad (1)$$

b) Staff costs: $$\min f_2(x)=\sum_{i=1}^{n}\sum_{j=1}^{m} HC_i\cdot t_{ij}\cdot x_{ij}\cdot Freq_j \quad (2)$$

c) Meal costs: $$\min f_3(x)=\sum_{i=1}^{n}\sum_{j=1}^{m} 1.1\cdot DC\cdot D_j\cdot t_{ij}\cdot x_{ij}\cdot Freq_j \quad (3)$$

d) Navigation costs： $$\min f_4(x)=\sum_{i=1}^{n}\sum_{j=1}^{m} NF_{ij}\cdot x_{ij}\cdot Freq_j \quad (4)$$

e) Airport costs: $$\min f_5(x)=\sum_{i=1}^{n}\sum_{j=1}^{m} (TLF_i+200+140\cdot D_j)\cdot x_{ij}\cdot Freq_j \quad (5)$$

Table 1: Model parameters

Parameter	Meaning
FF_i	Fuel flow of model i
FP	Jet fuel price
t_{ij}	Type of time it takes to fly the route j
$Freq_i$	Daily flight frequency
HC_i	Unit time staff cost for aircraft i
DC	Cost of a single economy class meal
D_j	Passenger demand on route j
NF_{ij}	Navigation fees for flight route j of type i
TLF_i	Take-off and landing costs for model i
SN_i	the number of available seats in aircraft i
TM_i	the daily available time for model i

2.2. Multi-objective Programming Model Transformation

The model constructed in this paper is a multi-objective mixed-integer linear programming model. It is difficult to obtain the global optimal solution. Therefore, select the linear weighting method to transform the multi-objective programming model into a single-objective model. Obtain the value of each cost in the past season through the company's financial department, and divide the sum of the costs to get the weight.

The transformed single-target model is:

$$\min f(x)=0.48f_1(x)+0.20f_2(x)+0.06f_3(x)+0.14f_4(x)+0.12f_5(x) \quad (6)$$

2.4. Constraint Conditions

a) 0-1 variable constraint: $x_{ij}=\begin{cases}1 & aircraft\ i\ for\ route\ j\\ 0 & aircraft\ i\ not\ for\ route\ j\end{cases}$ (7)

b) Airline-type uniqueness constraint: $\sum_{i=1}^{n} x_{ij}=1 \quad (j=1,2\ldots,m)$ (8)

c) Traffic matching constraint: $\sum_{i=1}^{n} Freq_j \cdot SN_i \cdot x_{ij} \geq D_j (j=1,2\ldots,m)$ (9)

d) Daily usage time constraint: $\sum_{j=1}^{m} Freq_j \cdot t_{ij} \cdot x_{ij} \leq TM_i (i=1,2\ldots,n)$ (10)

f) Flight continuity constraint: $x_{ij}=x_{ij'} (i=1,2\ldots,n; j=1,2\ldots,m)$ (11)

3. Case Study

3.1. Airline Database

An airline's Beijing branch is a full-service airline. Currently it manages three types of aircraft, namely A319-115, A320-232 and A330-200. The parameters of each model are shown in Table 2 and the relevant data of the route are shown in Table 3. The navigation costs NF_{ij} are obtained from the airline department.

Table 2: Fleet related data

Related parameters	Aircraft type		
	i=1(A319-115)	i=2(A320-232)	i=3(A330-200)
Number of aircrafts	2	2	2
FF_i （ton/hour）	2.35	2.57	6
TM_i （Hours / frame）	15	14	13
TLF_i （Yuan / time）	2920	3220	10448
HC_i (Yuan / hour)	2500	2500	3050
FP （Yuan / ton）		4050	
DC （Yuan / serving）		21	

Table 3: Route related data

number	route	t_{ij} (hour)			D_j (people)	$Freq_i$	Segment mileage (km)
		i =1	i =2	i =3			
1	Beijing-Jixi	1.67	1.67	1.65	85	1	1412
2	Beijing-Manzhouli	1.86	1.86	1.84	155	1	1574
3	Beijing-Erenhot	0.81	0.81	0.81	90	1	690
4	Beijing-Baotou	0.68	0.68	0.68	95	1	579
5	Beijing-Urumqi	3.35	3.35	3.33	140	1	2842
6	Beijing-Qingdao	0.76	0.76	0.76	170	1	646
7	Beijing-Xining	2.10	2.10	2.08	120	1	1780

8	Xining-Yushu	0.79	0.79	0.78	120	1	670
9	Beijing-Lijiang	3.04	3.04	3.01	130	2	2574
10	Lijiang-Xishuangbanna	0.68	0.68	0.68	130	2	577
11	Beijing-Yichang	1.75	1.75	1.74	130	1	1483
12	Yichang-Haikou	1.57	1.57	1.56	130	1	1333
13	Beijing-Hangzhou	1.42	1.42	1.41	160	1	1200
14	Beijing-Xiamen	2.09	2.09	2.08	170	1	1774

Using LINGO software to solve the original model which is called the primary optimization model. The optimal solution of the first optimization model is 287070.

3.2. Model Solution

In this section, this article starts with the idea of flight frequency for optimization. The model was improved by removing the restrictions on flight frequency, and capacity-demand matching was taken as the core to explore whether a better solution could be obtained. The improved model is called the secondary optimization model. To improve the model, we need to delete $Freq_j$ in the original model and no longer restricts x_{ij} to a 0-1 variable, and only constrains it to a non-negative integer. The output of the second optimization model is shown in Fig1.

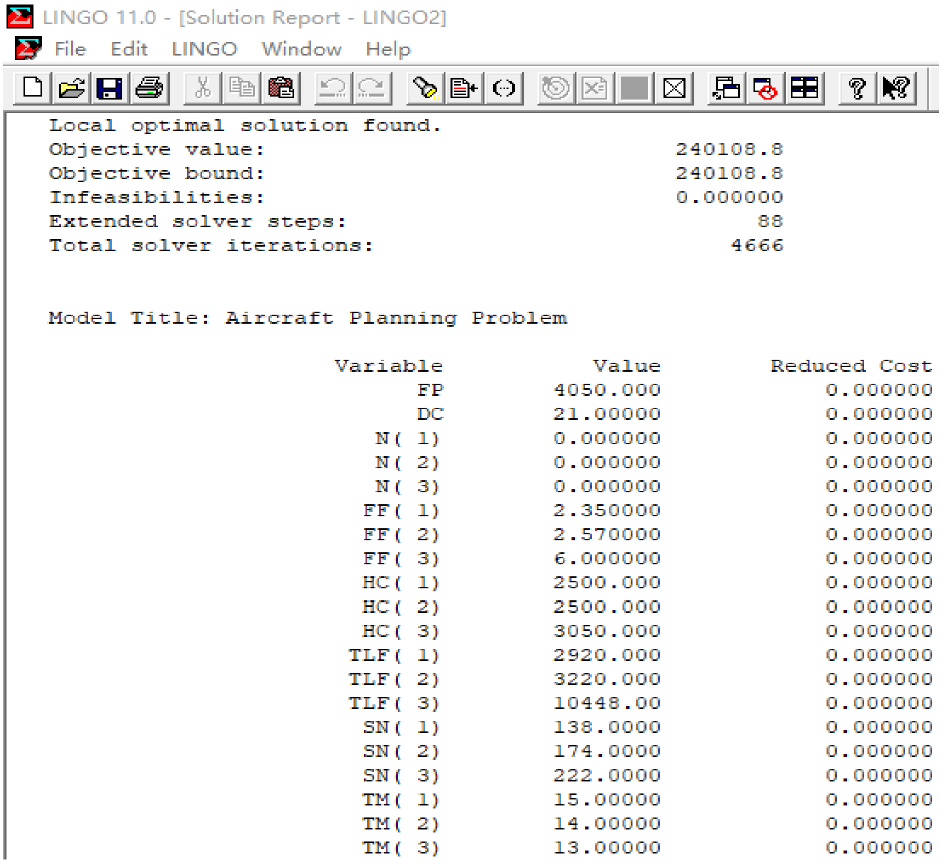

Figure 1: Input results of the second optimization model

As shown in Figure 1 the optimal solution value of the second optimization model is 240109.

Analyzing Table 3, it is found that the average passenger capacity of some feeder routes is small, which is far from reaching the economic status. In addition, the existing A330-200 in the fleet has only one route arranged in the plan, which resulting in great resource waste. Consider replacing one A330 in the fleet with an ERJ190 to see if the fleet plan can reach a more economical state.

Using LINGO software to solve the model of the new scheme, the global optimal solution value of the new scheme's primary optimization was 262269. The secondary optimization of the new scheme is 237608.7.

3.3. Results and Analysis

The optimized utilization and DOC of each model are shown in Table 4.

Table 4: Analysis of optimization results

		utilization of A319-115	utilization of A320-232	utilization of A330-200	utilization of ERJ190	DOC	Reduction in DOC
original scheme	Company planning	68.87%	99.29%	82.69%	-	301337	-
	Primary optimization	73.80%	99.81%	46.23%	-	287070	4.73%
	Secondary optimization	95.94%	96.48%	24.38%	-	240109	20.32%
new scheme	Primary optimization	66.20%	84.87%	48.77%	63.57%	262269	12.96%
	Secondary optimization	66.20%	96.48%	48.77%	63.57%	237609	21.15%

As can be seen from the above table, after adjusting the ratio of mainline and regional airliners, the DOC has been significantly reduced, which proves that a reasonable ratio of mainline and regional airliners can significantly reduce the DOC of airlines, thereby improving the competitiveness of airlines.

4. Conclusions

This paper comprehensively considers five costs to establish a multi-objective fleet planning model, then transformed into a single-objective model by a linear weighting method. Taking the real data of a airline as an example, the primary and secondary optimizations are performed respectively for fixed and non-fixed flight frequencies. According to the actual situation of the company, from the perspective of regional aviation, a dry-branch mixed fleet planning scheme is proposed and optimized twice. The results shows that the DOC is reduced by 4.73% when using the pure optimization scheme; and the DOC is reduced by 12.96% when using the dry-branch mixed scheme. It is proved that for a specific scenario, the dry-branch mixed solution can reduce DOC more significantly. In addition, if the restrictions on the frequency of flights are lifted, the DOC can be further reduced.

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