Flight Delay Cost Optimization based on Ground Power Supply

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Abstract. The flight delay induces extra cost to airlines and passengers. In the process of flight delay, the cost to maintain the engine power supply is the primary part of delay loss. This paper takes different power supply modes in to account to improve the previous flight delay cost model. As well this paper gets an in-depth analysis of total ground flight delay cost trend over time using electrical power or APU (auxiliary power units) for power supply. Taking the most popular aircraft B737, A320, A340 and B747-200 as examples, the paper conducts computer simulation for delay cost and loss ratio by using this model. The results indicate that the model can make a quantitative analysis of flight delay cost and reflect the economic advantage of the electrical power for long period delay. Therefore, it can provide reliable tools for airlines to optimize the operating costs.

Introduction

The flight ground delay not only causes energy waste and increases airline operation costs, it also produces waste gas and noise which pollute the environment. Therefore, research on the flight delay cost and analysis of cost optimization using the clean energy quantization has important practical significance to implement energy conservation and emission reduction work. While the relevant foreign research[1-2] results cannot be applied directly to the airports in China. Moreover, the former relevant research[3-4] has not taken the different delay cost under the conditions of the power supply in different ways and passengers waiting in different circumstances into consideration. When the flight delay occurs, the APU and the electrical power can be adopted for power supply. But there are obvious differences among these methods. This paper considering the optimal delay cost, and puts forward the new flight delay loss model, then make the qualitative and quantitative study of relation between the delay cost and delay time.

Flight delays loss model structure

2.1 Flight delays form

This paper divides the total economic loss of flight delay $C(t)$ into two parts: the first part is the passenger economic loss $C_1(t)$; the second part is the airline's economic loss $C_2(t)$. Among them, the airline economic loss $C_2(t)$ includes three parts. When the flight delay occurs and with APU power supply, the first part is related to fuel consumption, known as oil fee $C_{21}(t)$; The second part is for the crew costs $C_{22}(t)$; The third part is the airline losses in terms of passengers $C_{23}(t)$. And when the flight delay occurs and aircraft chooses electrical power for power supply, the three parts are as follows: The first part is the airlines to the airport to pay fees for the use of the electrical power for power supply $C_{22}^{'}(t)$; The other two parts are the same as choosing APU for power supply.

2.2 Explanation of parameters

N_p: The number of passengers (unit: people); N_k :A certain type aircraft fuel per unit time when using the APU power supply (unit: t/h); M :Unit weight fuel price(unit: yuan/t); k : The proportion of refund passengers when flight delay occurs; x : The average economic loss per unit time of each passenger when flight delay occurs (unit: yuan); N_i : The number of flight crew for each position (unit: people); F_i : Flight crew hourly fee for each position (unit: yuan/t); P_{B1} : Jane meals of each passenger waiting in the cabin when flight delay occurs (unit: yuan); P_{B2} : Catering cost of passengers waiting in the cabin outside when flight delayed and over a certain period of time (unit: yuan); P_T : The average refund (unit: yuan); P_R : The accommodation for each passenger (unit: yuan).

2.3 Model construction

Passenger economic losses when flight delay occurs:

$$C_1(t)=\begin{cases}0, t<t^{'}\text{ min}\\ N_p(1-k)xt, t\geq t^{'}\text{ min}\end{cases} \tag{1}$$

This paper assumes that when the flight time is less than $t^{'}$ min, the waiting time is tiny enough to be neglected in economic loss;

When flight delay occurs, airlines economic loss $C_2(t)$ is differentiated into the following three conditions:

(1)When using the APU for power supply, its total economic loss is:

$$C(t)=C_1(t)+C_2(t) \tag{2}$$

The economic loss of Airlines is:

$$C_2(t)=C_{21}(t)+C_{22}(t)+C_{23}(t) \tag{3}$$

The APU fuel consumption cost is:

$$C_{21}(t)=\begin{cases}0, t<t^{'}\text{ min}\\ N_k Mt, t\geq t^{'}\text{ min}\end{cases} \tag{4}$$

Flight crew cost is:

$$\boldsymbol{C_{22}(t)=\begin{cases}0, t<t^{'}\text{ min}\\ \sum N_i F_i\left[\frac{t-30}{60}\right], t\geq t^{'}\text{ min}\end{cases}} \tag{5}$$

The airline loss in terms of passengers is:

$$C_{23}(t)=\begin{cases}0, t<t^{'}\\ P_{B1}N_p(1-k)+P_T N_p k, t^{'}\leq t<t_1\\ (P_{B1}+P_{B2})N_p(1-k)+P_T N_p k, t_1\leq t<t_2\\ (P_{B1}+P_{B2}+P_R)N_p(1-k)+P_T N_p k, t\geq t_2\end{cases} \tag{6}$$

(2)When using the electrical power for power supply, its total economic loss is:

$$C^{'}(t)=C_1(t)+C_2^{'}(t) \tag{7}$$

The economic loss of Airlines is:

$$C_2^{'}(t)=C_{21}^{'}(t)+C_{22}(t)+C_{23}(t) \tag{8}$$

The fees that the airlines pay to the airport for the use of the electrical power for power supply are:

$$C_{21}^{'}(t)=\begin{cases}\left(\frac{t}{15}\right)45, t=15n\\ \left(\left[\frac{t}{15}\right]+1\right)45, t\neq 15n\end{cases} \tag{9}$$

Note: The fees that the airlines pay to the airport for the use of the electrical power for power supply are charging per 15 min phases, which means although the time is less than 15 min, it still counts 15 min, and the fee is 180 RMB per hour.

(3) When early predict the occurrence of flight delay, passengers have been waiting in the airport terminal, the total economic loss (including total loss of passengers and airlines) is:

$$C^{''}(t)=\begin{cases} N_p(1-k)[xt+(P_{B1}+P_{B2})]+P_T N_p k, t<t_2 \\ N_p(1-k)[xt+(P_{B1}+P_{B2}+P_R)]+P_T N_p k, t>t_2 \end{cases} \tag{10}$$

The numerical simulation

This paper assumes that the delayed flight models is A340-600 aircraft, and using the model shown in this paper to calculate different conditions of flight delay changes with time metabolic trend.

3.1 Economic loss analysis by using different ways for power supply

In the model already structured, while using the above parameters and passengers waiting in the cabin, the total economic loss using APU for power supply $C(t)$ and the total economic loss using electrical power for power supply $C^{'}(t)$ are as shown in figure 1:

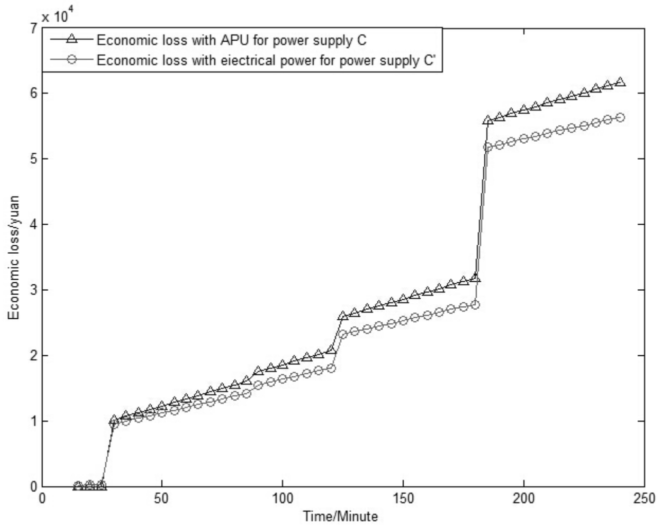

Fig.1 economic losses of A340-600 with different power supply mode

It can be seen from Figure 1, when the passengers are waiting in the cabin in the interval [25-180], the total economic loss using electrical power for power supply is less than the total economic loss using APU for power supply, and the loss is proportional to the time difference. Thus it comes to a conclusion: when the flight delay occurs, aircraft using electrical power for power supply is more economical than using APU for power supply which is consistent with the actual survey results.

3.2 Cost optimization analysis of using electrical power

Considering the aircraft may be different when flight delay occurs, and the difference of economic loss between passengers waiting in cabin and waiting in the terminal, aircraft which are B747-400, A330-200 and B737-800 are necessary to be added to compare. From the above sources we can conclude that the delay loss of using electrical power is less than APU. With respect to APU, when the aircraft using electrical power, the delay loss ratio is showed as Fig.2.

It can be seen from Figure 2, the delay loss ratio of B747-400 is largest. The peak value is approximately 16%. The delay loss ratio of A330-200 and A340-600 are also larger than B737-800. The peak values are approximately 13.5% and 13%. The delay loss ratio of B737-800 is smallest. The peak value is approximately 10.6%. This is because the capacity and hourly fuel consummation of B747-400 are more. After using electrical power, the differences between the economic losses of APU per hour and charging fees are larger, so economic saving rate is higher. Accordingly, providing electrical power has a significant effect on optimizing the airlines operating costs and reducing operation fuel consumption in the large transport hub.

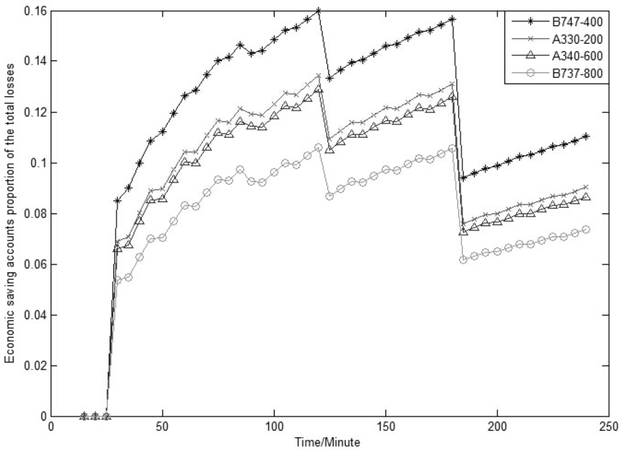

Fig.2decrement rate of delay loss of different models using ground power

Conclusion

This paper analyzes the main factors of flight delay lose and constructs flight ground delay lose model on account of different power supply model and delay circumstances. And this paper uses the mainstream aircraft types for simulation. The results shows that, the model of this paper can refine formation of flight delay lose and make a quantitative analysis of flight delay cost differences under different power supply model and delay model. So through the analysis above, this paper can get the conclusion that different power supply model have profound impact on flight delay economic loss. Comparing with APU, electrical power‘s economic advantage is obvious. The electrical power can save delay cost.

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