Analysing Commercial Aircraft Landing Cost with Airport Attributes and Case Study

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Abstract: This paper mainly studies the relationship between airport intrinsic factors and aircraft landing cost. It turns out that the cost of the descent is related to some environmental factors because the landing process is different from the cruise process. In the process of cruising, all the behaviors of the aircraft are related to the behaviors and weather of the pilots. In addition to the participation of the aircraft, the landing process also has a great deal to do with the airport where the aircraft lands. So the environmental factors of the airport also have a lot to do with the fuel consumption during landing. Considering the impact of airport factors on aircraft landing, through modeling and analysis of the airport, this paper discusses the impact of the airport environment and management factors on aircraft landing fuel consumption. Taking 13 major airports in China as the analysis target, this paper analyzes the characteristics of these 13 airports and points out the focus of management investment in different airports and the corresponding reasons.

1. Introduction

Air transportation has produced a dramatic increase over the past several decades and is expected to produce at a high rate in the future. With the rapid development of civil aviation, flight delays and airport congestion are becoming more and more serious. The ways to reduce congestion are the physical expansion of airport infrastructure and improve the management modes for airports. However, the expansion of the airport has only temporarily eased traffic congestion by stimulating new demand growth.

2. Literature review

Congestion at runways are made chiefly by incorrect predictions of landing times, increased air aid and higher common landing times. For the forecast of aircraft landing time, the analysis is almost satisfactory [1]. In relationship to delay propagation during the air transport system, many investigations have given the complexity of the system [2-4] and the possible impact of delays on the system's dependability and capacity to improve [5-8].

With the uniform increase in air transportation request, the current air system is meeting capability problems, leading to delays and congestions. One of the most significant parts is the runway. The increasing use of full airfield capacity will adversely impact predictability and punctuality. European SESAR (Single European Sky ATM Research) program [9] and FAA' s NextGen (Next Generation Air Transportation System) plan [10] aims to improve the system transportation throughput in order to provide the forecast demand with a sufficient margin. However, there are few specific studies on the management strategies to be adopted by different airports and the impact of different airport environments on aircraft landing. Because of this situation, this paper puts forward the relationship between the airport management status and the average landing time of the aircraft, to analyze the differences in the management strategies to be adopted by different airports. These are the research directions of this paper.

3. Landing cost factor

3.1 attribute of airports

In this paper, we study the relationship between inherent factors of airport and landing cost, the relationship between the facts show that consumption is related to some environmental factors in the process of the landing because the plane's landing process is different from the cruise. When the plane in the process of the cruise, all the cost of aircraft related to the behavior of the pilot and the weather. Landing process also affected by the airport, so the environmental factors also affect the cost of the consumption when aircraft is landing. We summarized the factors to five attributes: the altitudes of the airport, latitudes of the airport located in, distance to the coast, the ratio of the number of landing and take off to the area for passager waiting, and the slot number. The results of a correlation analysis of various input and output variables of the attributes for three kinds of plane are displayed in Table.

Table 1. Results of a correlation analysis of airport attributes

Boeing 737/ Air Bus 320/ Air Bus 333	1	2	3	4	5	6	7
1. altitudes	1/1/1						
2. latitudes	0.05/0.05/0.05	1/1/1					
3. distance to the coast	0.54/0.54/0.54	0.08/0.08/0.08	1/1/1				
4. ratio	-0.11/-0.11/-0.11	-0.07/-0.07/-0.07	-0.11/-0.11/-0.11	1/1/1			
5. slot number	-0.08/-0.08/-0.08	0.18/0.18/0.18	-0.21/-0.21/-0.21	0.65/0.65/0.65	1/1/1		
6. fuel consumption	-0.53/-0.49/-0.31	-0.32/-0.41/-0.31	-0.48/-0.46/-0.33	0.64/0.53/0.49	-0.42/-0.55/-0.65	1/1/1	
7. average landing time	-0.49/-0.47/-0.38	-0.29/-0.42/-0.36	-0.42/-0.39/-0.41	0.55/0.48/0.54	-0.39/-0.50/-0.6	0.82/0.83/0.91	1/1/1

3.2 Costs of landing

3.2.1 Airline cost

When flights are delayed, the main cost is the operating cost of the airline. The b737-800 in service has a total effective flight time of about 200,731.01 hours. The total operating cost in this process is 7027,673,362.52 yuan, including 107,906,114.53 yuan for ground fuel and 2,050,216,157.10 yuan for air transport, totaling 2,158,122,271 yuan. On this basis, we can calculate the unit operation cost of 574.55 yuan/min.

3.2.2 Passenger cost

Because of delays caused by airport congestion, passenger costs are measured in terms of time value. The time value of domestic leisure tourists is 50 yuan/hour, while that of business or international tourists is 100 yuan/hour. Suppose (1) leisure and business account for 8:2, (2) 160 seats for domestic flights and 320 seats for international flights, (3) the average passenger cost of flights is 179RBM/min, under the condition that the load coefficient is 80%.

3.2.3 Environmental cost

Environmental externalities during landing mainly come from gas emissions, which is why we remove the noise portion. Alternatively, we cover each gas at the cost of RMB 3 per kilogram of fuel. According to He (2006), b737-800 is provided with two 1ge034-cf34-3alec engines. According to ICAO aircraft engine effusion database, its fuel burning at arriving is 49.6g /s. Consequently, the environmental cost is 18 yuan/min.

4. Model

4.1 model description

At an airfield, supply can refer to the contents of a runway, which can contain only one plane at a given time. Nevertheless, for aviation setting in order to arrive and take off, there is congestion on the taxiway leading to the runway. As pointed in the Figure 1, just like Rong [11] has introduced, the horizontal axis is the landing time of the plane that needs to arrive at time t. The vertical axis is the cost of landing time. Cost party includes airline operation cost, passenger time cost and environmental cost.

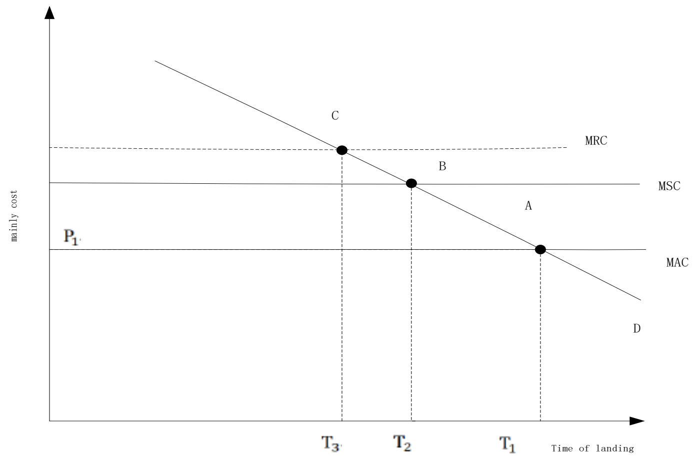

Figure 1. Model description

$$C = (P_a + P_p + P_e) \cdot T + c \tag{1}$$

In this model, we denote P_r as the value of operation, means the cost savings resulting from the reasonable scheduling of aircraft at the airport. Because P_r has no effect to the other attributes of the cost in landing, so we assume that P_r only affects the landing time rather than the total cost.

So:

$$C_B = (P_a + P_p + P_e) \cdot T_2 + c \tag{2}$$

$$C_c = (P_a + P_p + P_e + P_r) \cdot T_3 + c \tag{3}$$

$$C_C - C_B = (T_3 - T_2)(P_a + P_p + P_e) + P_r T_3 = 0 \tag{4}$$

Then:

$$P_r = \frac{(T_2 - T_3)(P_a + P_p + P_e)}{T_3} \tag{5}$$

As we can see from the equation, the value of P_r is only related to the decrease of landing time, the greater the value of P_r, the more time will decrease when aircraft is landing.

In order to calculate the different value of operation in different airports, we denotes $F_{(\theta)}$ as the impact of construction and environment of different airports on the total consumption of aircraft during landing, and then we denotes ε as the fuel consumption parameters of the same aircraft when descending from different airports in unit time.

$$F_{(\theta)} \cdot C = (\varepsilon P_a + P_p + P_e + P_r) \cdot T + c \tag{6}$$

We assume that value of the $F_{(\theta)}$ is 0 to 1, and $f_{(\theta_i)}$ means different to the influence factor to $F_{(\theta)}$.

Table 2. Parameter of $F_{(\theta)}$

$f_{(\theta_1)}$	influence factor of altitudes	n_1	Number of altitudes	δ_1	correlation index of altitudes
$f_{(\theta_2)}$	influence factor of dimension	n_2	Number of dimension	δ_2	correlation index of dimension
$f_{(\theta_3)}$	influence factor of distance to the coast	n_3	Number of distance to the coast	δ_3	correlation index of distance to the coast
$f_{(\theta_4)}$	influence factor of ratio	n_4	Number of ratio	δ_4	correlation index of ratio
$f_{(\theta_5)}$	influence factor of slot number	n_5	slot number	δ_5	correlation index of slot number

$f_{(\theta_i)} = \left(1 - \frac{n_i - n_{i_{min}}}{n_{i_{max}} - n_{i_{min}}}\right)\frac{|\delta_i|}{\sum_{i=1}^{5}|\delta_i|}$ when i=1,2,3,5. $f_{(\theta_i)} = \left(\frac{n_i - n_{i_{min}}}{n_{i_{max}} - n_{i_{min}}}\right)\frac{|\delta_i|}{\sum_{i=1}^{5}|\delta_i|}$ when i=4.

We assume a basic airport with $P_{r0}=0$, total cost of landing is $F_{(\theta_0)} \cdot C$, which C is the basic value of the landing cost. Then we can calculate the cost of landing in airport1 below:

$$F_{(\theta_0)} \cdot C = (\varepsilon P_a + P_p + P_e + P_{r0}) \cdot T_0 + c \quad (7)$$

$$F_{(\theta_1)} \cdot C = (\varepsilon P_a + P_p + P_e + P_{r1}) \cdot T_1 + c \quad (8)$$

Equations subtract:

$$P_{r1} = \frac{(\varepsilon P_a + P_p + P_e)(T_0 - T_1) + P_{r0}T_0 - (F_{(\theta_0)} - F_{(\theta_1)})C}{T_1} \quad (9)$$

4.2 Value of operations in different airports

We assume value of operation in SYX when airbus 320 landing on it as the basic value of P_r, other P_r of different airports shows below:

Table 3. Value of operations in different airports

		$F_{(\theta)}$	ε	Fuel cost	Average landing time	P_r
SHE	737	0.755	0.715	46.9	24	371.25+(5.54*10-3/24)*C
	320	0.762	0.723	51.4	26	280.38+(4.85*10-3/26)*C
	333	0.753	1.514	95.2	23	582.34+(5.87*10-3/23)*C
PEK	737	0.670	0.885	38.7	16	961.88+(13.62*10-3/16)*C
	320	0.655	0.740	36.4	18	765+(12.94*10-3/18)*C
	333	0.616	1.715	70.3	15	1294.17+(18.13*10-3/15)*C
CGO	737	0.773	0.780	27.7	13	1370.77+(8.85*10-3/13)*C
	320	0.783	0.847	30.1	13	1284.05+(8.08*10-3/13)*C
	333	0.751	1.367	52.3	14	1596.57+(9.79*10-3/14)*C
XIY	737	0.455	0.793	32.5	15	1080+(28.87*10-3/15)*C
	320	0.499	0.809	35.4	16	967.23+(24.31*10-3/16)*C
	333	0.472	1.448	55.4	14	1576.68+(29.71*10-3/14)*C
NKG	737	0.803	0.762	37.5	18	754.23+(4.72*10-3/18)*C
	320	0.824	0.736	38.2	19	682.11+(5.54*10-3/19)*C
	333	0.779	1.416	65.8	17	1031.65+(5.54*10-3/17)*C
HGH	737	0.731	0.839	34.4	15	999+(10.47*10-3/15)*C
	320	0.767	0.946	36.2	14	1199+(8.64*10-3/14)*C
	333	0.715	1.607	61.5	14	1497.78+(12.36*10-3/14)*C
PVG	737	0.635	0.748	45	22	478.64+(1.15*10-3/22)*C
	320	0.624	0.847	48.6	21	540+(12.57*10-3/21)*C
	333	0.536	1.434	82.3	21	963.12+(16.76*10-3/21)*C
CTU	737	0.377	0.824	33.8	15	1021+(34.07*10-3/15)*C
	320	0.433	0.832	36.4	16	942.34+(28.44*10-3/16)*C
	333	0.436	1.500	61.5	15	1386.34+(30.13*10-3/15)*C
WUH	737	0.777	0.785	32.2	15	1132+(7.4*10-3/15)*C
	320	0.802	0.930	35.6	14	1215+(6.14*10-3/14)*C
	333	0.759	1.620	66.4	15	1315.29+(8.6*10-3/15)*C
SZX	737	0.763	0.712	54.5	28	202.5+(4.46*10-3/28)*C
	320	0.827	0.704	55.8	29	167.59+(2.1*10-3/29)*C
	333	0.755	1.248	85.3	25	523.74+(5.32*10-3/25)*C
KMG	737	0.488	0.699	34.4	18	788.23+(22.22*10-3/18)*C
	320	0.550	0.695	36.1	19	694.15+(17.79*10-3/19)*C
	333	0.552	1.350	66.4	18	1103.64+(18.67*10-3/18)*C
CAN	737	0.624	0.749	53.2	26	291.43+(10.15*10-3/26)*C
	320	0.682	0.814	55.6	25	324+(8.24*10-3/25)*C
	333	0.598	1.200	85.3	26	543.82+(11.15*10-3/26)*C
SYX	737	0.807	0.734	64.2	32	75.93+(2.53*10-3/32)*C
	320	0.888	0.649	62.1	35	0
	333	0.827	1.283	91.2	26	543.82+(2.35*10-3/26)*C

Congestion fees lead to rapidly increasing costs for airlines, especially at peak hours, causing airlines to adopt a series of countermeasures. Countermeasures can include rescheduling a flight from a highly congested time to a less congested time, using a larger aircraft, or even canceling the route if the fee is extremely high. Regardless of how the airlines respond, congestion fees lead to "peak shaving and valley filling" that is, reducing flight frequency in peak hours and increasing resource utilization in off-peak hours.

5. Discussion

5.1 Influence of passenger flow

The following figure and table show the comparison of passenger flow of each airport:

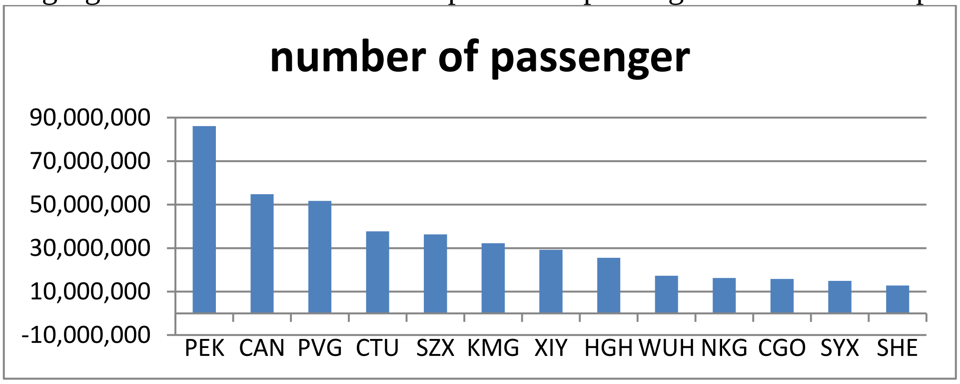

Figure 2. Number of passenger of each airport

It can be seen from the table that after adding the passenger flow volume of the airport, we use the σ to represent the management efficiency of different airports in different passenger flow situations. From the table above, it can be seen that the largest passenger flow volume is PEK airport, and PEK airport can still achieve a relatively high P_{rm} value in the case of maximum passenger flow. For 737, the optimal σ value is 82.85, while most of the remaining values are below 40. After excluding PEK at the highest level and SYX at the lowest level, the optimal result is 40.68 of CTU airport instead of CAN and PVG at the highest passenger flow volume.

5.2 Influence of busy time

Table 4. Landing time of each airport in different time in each day

Airport code		00:00-06:00	06:00-10:00	10:00-14:00	14:00-18:00	18:00-21:00	21:00-24:00	standard deviation
SHE	737	13	32	28	24	23	17	6.968979
	320	12	36	30	26	25	17	8.687155
	333	13	31	24	23	22	14	6.735478
PEK	737	14	22	18	16	16	15	2.857738
	320	16	25	19	19	18	17	3.162278
	333	14	21	16	14	15	15	2.639444
CGO	737	11	21	16	14	13	12	3.619392
	320	12	20	18	14	13	13	3.224903
	333	11	17	16	15	14	12	2.316607
XIY	737	13	22	19	16	15	14	3.391165
	320	14	23	20	15	15	17	3.50238
	333	11	19	18	14	13	14	3.060501
NKG	737	14	24	21	18	17	14	3.949684
	320	15	26	22	19	18	15	4.262237
	333	11	22	19	17	16	13	3.983298
HGH	737	12	25	18	15	15	13	4.718757
	320	13	23	16	15	14	14	3.656045
	333	11	21	16	15	14	12	3.544949
PVG	737	14	29	28	23	21	15	6.314006
	320	15	31	26	22	20	14	6.501282
	333	13	24	26	22	19	14	5.316641
CTU	737	15	24	19	16	14	13	4.070217
	320	16	26	21	17	17	15	4.131182
	333	13	21	17	14	14	12	3.311596
WUH	737	12	25	18	16	14	13	4.760952
	320	12	25	21	15	14	13	5.163978

	333	11	20	17	14	13	12	3.391165
SZX	737	12	38	35	30	26	14	10.77806
	320	12	41	37	30	27	14	11.8223
	333	11	31	27	27	23	13	8.173127
KMG	737	13	26	24	20	17	14	5.291503
	320	12	28	26	21	20	16	5.991661
	333	11	22	22	20	17	14	4.501851
CAN	737	12	36	31	28	22	14	9.558591
	320	13	35	33	29	23	16	9.042492
	333	11	31	29	27	20	14	8.294577
SYX	737	12	39	36	33	24	13	11.72035
	320	13	42	39	36	22	14	12.94089
	333	11	33	31	28	20	12	9.607289

We can see from the chart above, for the airport with shorter landing time, especially the PEK, CYU, XIY, airport in terms of their landing time difference between the peak flow peak peace rather smaller, they in the trough (00:00 – 06:00) during the period of the landing time of general average is around 15 min, but the average land long CAN three, SYX, SZX airport landing in average trough time is shorter, usually within 11-13 min. Objectively shows the more from itself, from the airport CAN, SYX, SZX has landed the plane fast ability, and eventually make the plane's landing, the average time longer more time because the airport cooperative ability is poor, cannot achieve coordinated by the plane's landing order, to realize the interaction between the peaks and troughs, leading to longer landing time and greater land costs.

6. Conclusion

From the above analysis, we can draw the following three conclusions:

(a) Passenger flow is not the biggest factor in reducing costs. Passenger flow can only represents the busy degree of the airport to a certain extent, and the busier the airport is, the more inclined to strengthen airport construction and management. These factors will lead the airport aircraft landing costs to reduce. For example, in the comparison between PEK airport and other airports mentioned above, the daily passenger flow of the PEK far exceeds that of other airports. Meanwhile, the management increment P_{rm} value of PEK airport is also relatively large.It can be considered that since the management input of PEK is relatively large, the management increment brought by PEK is also relatively large. Therefore, for other12 airports, PEK's management mode is worth learning from. Under the same or similar passenger flow and the scale of aircraft takeoff and landing, PEK has a strong management ability that brings a relatively large management increment.

(b) The efficiency gap between different airports may vary greatly. Airports with more efficient management will know better about how to make use of their busy and free time. Tilting the capacity from busy time to idle time and increasing the take-off and landing of idle time aircraft can alleviate the number of aircraft taking off and landing during peak hours. Making a schedule for the aircraft to take off and land can get lower landing costs. Even from the standard deviation of takeoff and landing time per day, different airports have relatively large differences. The smallest variance is PEK airport for 737 and 320 aircraft and CGO airport for 333 aircraft respectively.

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