2012 International Conference on Economics, Business Innovation
IPEDR vol.38 (2012) © (2012) IACSIT Press, Singapore

Factorial Study on Airport Delay for Flight Scheduling Process

Fairuz I. Romli[+], Tan Kai Jun, Teong Chee Khoon, Ong Thiam Chun and Koo Teck Hock

Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

Abstract. This paper presents the study on the contributing factors of airport delay based on the parameters decided during flight scheduling process. It is believed that the timing of the scheduled departure will have a significant impact on the level of airport delays that could be anticipated for the flight. Three major airports in the United States: Atlanta's Hartsfield-Jackson (ATL), New York's John F. Kennedy (JFK) and also San Francisco International Airport (SFO) have been selected as the example case studies. Overall, the ANOVA results show that scheduling parameters: "day", "month" and "departure time" significantly affect the airport delay and should be included in the prediction model.

Keywords: flight delay, flight scheduling, airport delay

1. Introduction

Due to the significant increase in air transportation demands, the issues of flight delay have become more prominent. One of the main contributing factors to this problem is the airport capacity, which is constrained by the capacity limits of its terminal airspace, runway system, taxiway system, gate and terminal building [1]. During rush hours especially, many airports are operating at their full capacity. It is impossible to expect the airlines to back down on their flight scheduling just to avoid delay. Unlike other industries, unfilled seats on any commercial transport flight are unrecoverable losses. As observed on one particular morning, though the departure capacity at New York's John F. Kennedy Airport (JFK) can cope with a maximum of 52 flights per hour, 59 flights were scheduled to depart the airport between 9am to 9.59am [2]. Automatically, this means at least seven flights would be delayed. It is not that airlines do not realize the possibility of such drawback but they do not want to lose passengers to their competitors or allow any seat demands left unsatisfied. Back in 1990, over 20,000 hours of delay were reportedly incurred at each of 21 airports in the United States [3]. It should be highlighted however that flight delay is not caused only by airport capacity limits. Among others, airline management, weather, aircraft mechanical problem, aviation control and passenger problems can also play a big role in delaying a flight [4].

Regardless of the cause, departure delay prolongs the amount of time required to fly the aircraft from one airport to the other and it negatively affects the aircraft utilization rate. With their fleet of operational aircraft, it is essential for airlines to have proper scheduling to ensure that adequate utilization is achieved and profits are maximized. In current practice, flight scheduling is normally done once every two or three months and the process involves deciding on service route pairs, departure time and arrival time for flights that the airline wishes to offer [5]. Since it can be presumed that airlines tend to prioritize their flight scheduling to cater for the timing of peak passenger demands over avoiding delays, the latter is readily anticipated for many flights. By estimating potential delays to be endured for each flight segment, a better fleet management can be made possible during flight scheduling process. For instance, airlines can weigh in several scheduling alternatives and select the one that brings the largest profits to their operation with their limited available resources.

[+] Corresponding author. *E-mail address*: firomli@eng.upm.edu.my

This research paper is focused on analyzing delay that is anticipated for airport departure, particularly by linking it to decisions made during flight scheduling process. It is part of a much bigger initiative to develop a decision-making aid tool to facilitate airlines in managing their available resources during flight scheduling. Results from this analysis are useful in modeling of the estimated airport delay since it identifies significant factors to be included into the model. Data for three major US airports are used as example case studies to demonstrate the findings.

2. Airport Delay Data

To address the issues related to flight delay, all major airlines operating within US domestic markets are regulated by US Department of Transportation (DOT) to report on their monthly service quality performance. This data is made available online at http://www.transtats.bts.gov. In general, there is no standard definition for delay that is widely used within the industry [6]. The Bureau of Transportation Statistics (BTS) in DOT, which is responsible to collect and publish the airlines' service quality data, considers a flight to be delayed only if it leaves the gate more than 15 minutes from the originally scheduled departure time. However, in the context of this research study, the interest is on the total expected additional time that should be included for departing flights from the airport during flight scheduling process. This will reduce the amount of available time of the aircraft for operational utilization. Hence airport delay is defined here as the extra time for taking off at the airport in comparison to the expected ideal when no delay is incurred. In other words, it covers the duration of delay from leaving its departure gate up to when the aircraft finally takes off from the airport runway. The analysis does not differentiate the actual causes of the airport delay since the primary focus is to capture the modelling of total predicted amount of time delay for a flight that has been scheduled to depart from the airport at a particular departure time.

Fig. 1 shows the monthly average airport delay for all afternoon flights at the San Francisco International Airport (SFO) based on day of departure throughout 2010. The classification of flights follows the departure time groupings as defined in Table 1 [7]. From the visual assessment of Fig. 1, the recorded airport delay for each day seems to approximately follow similar quadratic trend within the yearly cycle. While this probably hints that the scheduling effects of "day" parameter may be rather insignificant, the variation of airport delay between them is still substantial to be ignored. To support this notion, the monthly average airport delay for afternoon flights departing John F. Kennedy Airport (JFK) is plotted in Fig. 2. It can be observed that while the overall trend appears different than that seen for SFO (potentially due to a different departure airport), the negative quadratic trend seems to be shared by the different lines corresponding to the departure days. In fact, the variation of values between the lines is much more significant than those for SFO.

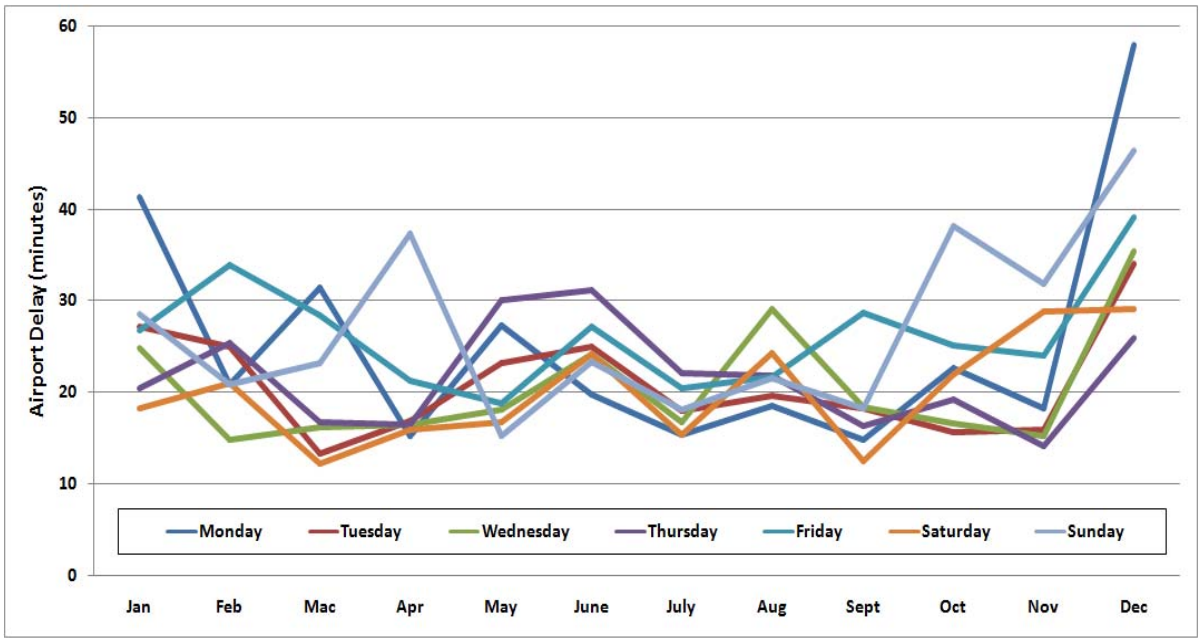

Fig. 1: Airport Delays for Afternoon Flights at SFO Airport in 2010

Table 1 : Departure Time Groups

Category	Time Group	Time Period
1	Morning	06.00 – 09.59
2	Day	10.00 – 15.59
3	Afternoon/Early Evening	16.00 – 19.59
4	Evening/Night	20.00 – 23.59

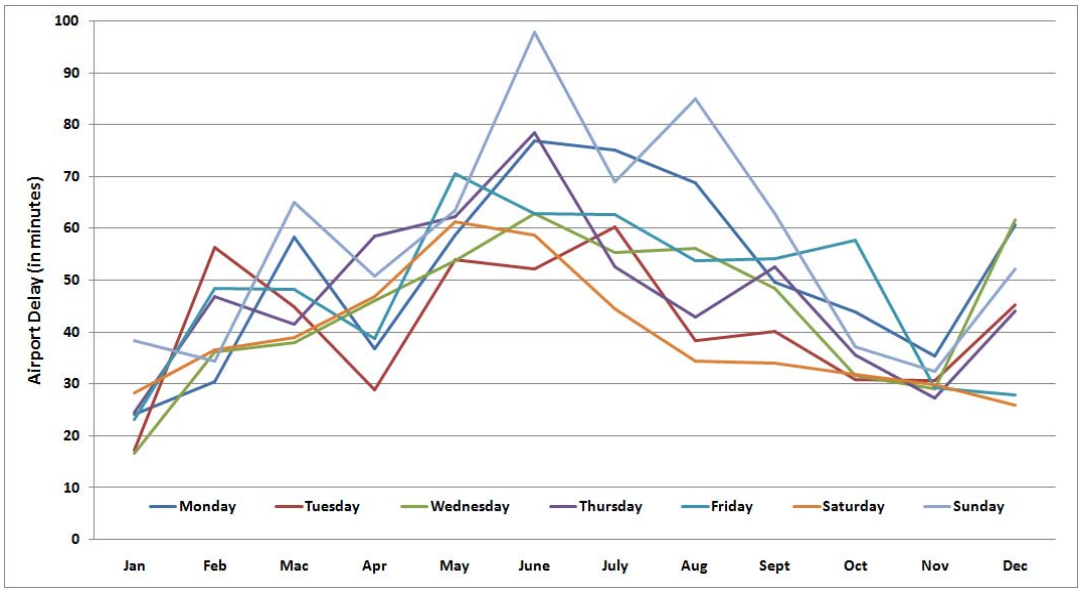

Fig. 2: Airport Delays for Afternoon Flights at JFK Airport in 2010

Another scheduling parameter that is believed to have an effect on airport delay is the departure time. As defined in Table 1, there are four departure time categories. To show potential effects of scheduled departure time, Fig. 3 is plotted for Monday flights departing Hartsfield-Jackson Atlanta International Airport (ATL). The sudden sharp increase in airport delay for the month of July, as can be seen in Fig. 3 for the morning and afternoon flights, is perceived to be just an anomaly, perhaps due to a bad weather condition by chance rather than a departure congestion due to scheduling by the different airlines. Airport delay for different selection of departure time generally appears to follows a similar trend to each other with different months. However, the level of difference in airport delay, especially throughout the summer season between the months of May and August, is still substantial enough to be ignored.

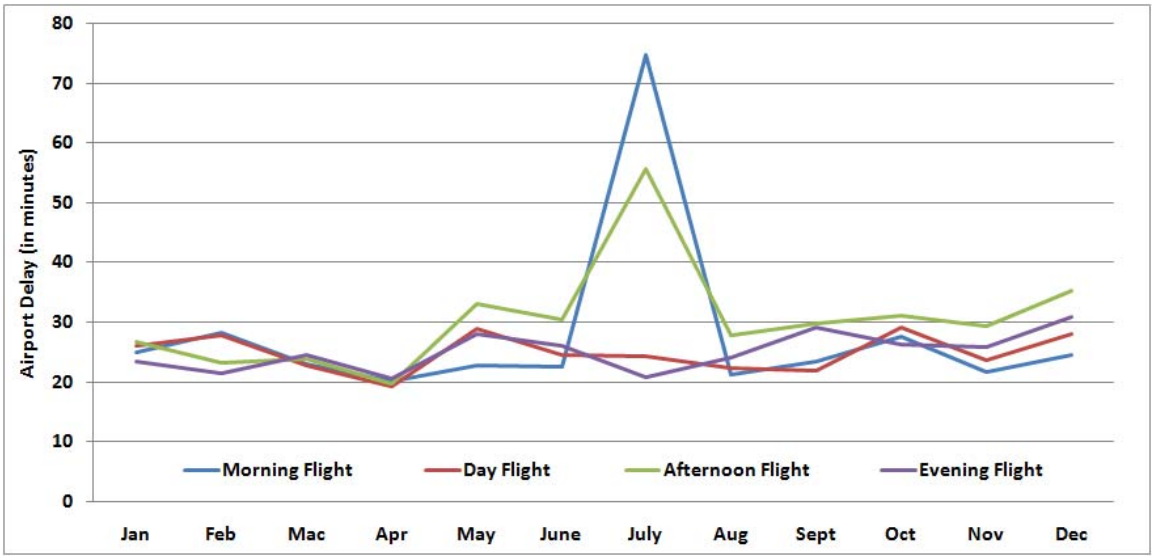

Fig. 3: Airport Delays for Departing Flights at ATL Airport in 2010

3. Factorial Analysis

It is hard to confidently conclude the significance level for day, month and departure time on the airport delay just by looking the above plots. In order to confirm these observations, a factorial ANOVA is done to study their effects to the anticipated airport delay. Apart from the individual effects of these factors, ANOVA also gives some information regarding the effects from their interaction or combination. Available data for three major airports (SFO, JFK and ATL) are used as sample case study, which are done separately analyzed to separate the effects of different departure airport. A full factorial analysis covering each airport will have a total of 336 data points with the levels of the considered factor as tabulated in Table 2. The analysis is done using MINITAB software and the result is presented in Table 3, Table 4 and Table 5. It should be noted that the processing of raw data obtained from the BTS website is done with following convention:

- Gate delay is the extra time taken to leave the gate after the scheduled departure time has passed
- Early gate departures are designated as zero instead of their negative time value
- Taxi delay is the extra time taken to finally take off after leaving the departure gate in comparison to that in the ideal case scenario
- Ideal taxiing time for takeoff at a particular airport is assumed to be the minimum recorded taxi out time in the raw data
- Airport delay is the summation of gate delay and taxi delay
- Some of the raw data that are considered to be "outliers" due to their extreme or irregular values are excluded from the calculation of the monthly average airport delay

Table 2 : Factors Level for ANOVA

Factor	Levels	No. of Levels
Day	Mon, Tues, Wed, Thurs, Fri, Sat, Sun	7
Month	Jan, Feb, Mac, April, May, June, July, Aug, Sept, Oct, Nov, Dec	12
Departure Time Group	Morning, Day, Afternoon, Evening	4

Table 3 : Factorial ANOVA Results for ATL

SOURCE	DF	SS	MS	F	P
Day	6	2465.80	410.97	10.30	0.00
Month	11	2912.59	264.78	6.63	0.00
Departure Time	3	3066.89	1022.30	25.62	0.00
Day*Month	66	8198.20	124.22	3.11	0.00
Day*Departure Time	18	1401.86	77.88	1.95	0.014
Month*Departure Time	33	3886.25	117.77	2.95	0.00
Error	198	7901.73	39.91		

Table 4 : Factorial ANOVA Results for SFO

SOURCE	DF	SS	MS	F	P
Day	6	1137.72	189.62	12.90	0.00
Month	11	5204.29	473.12	32.18	0.00
Departure Time	3	6559.86	2186.62	148.70	0.00
Day*Month	66	5236.31	79.34	5.40	0.00
Day*Departure Time	18	519.11	28.84	1.96	0.013
Month*Departure Time	33	1006.46	30.50	2.07	0.001
Error	198	2911.49	14.70		

Table 5 : Factorial ANOVA Results for JFK

SOURCE	DF	SS	MS	F	P
Day	6	3741.80	623.63	16.44	0.00
Month	11	14698.77	1336.25	35.23	0.00
Departure Time	3	21761.02	7253.67	191.24	0.00
Day*Month	66	10132.86	153.53	4.05	0.00
Day*Departure Time	18	1944.79	108.04	2.85	0.00
Month*Departure Time	33	14731.59	446.41	11.77	0.00
Error	198	7510.04	37.93		

Based on the ANOVA results, it shows that the parameters “day”, “month” and “departure time” are all indeed significant to airport delay as indicated by their corresponding high F-values and zero p-values. The results are consistent for all three airports, indicating the general applicability of this assessment for the other airports as well. In addition, their interaction effects also appear to be significant although not as high as their individual effects. Overall, this means that if the airport delay is to be modelled for flight scheduling process, these parameters should be considered to be in the model due to their significant effects.

4. Conclusion and Future Work

The main objective of this study is to analyze the factorial effects of several flight scheduling parameters to the amount of airport delay. Based on the ANOVA results, the parameters “day”, “month” and “departure time” are all significant factors to predict airport delay at any given departure airport. However, it is believed a better result can be obtained if the delay data is averaged for several years instead of just using data for one particular year. As such in the case with delay data for ATL shown in Fig. 3, the data abnormalities also can produce some biased effects in the ANOVA results. The next step forward is to have more airport delay data before the modelling can be done with respect to the scheduling parameters.

5. References

[1] Evans, A., *Rapid Modeling of Airport Delay*, in *12th Air Transport Research Society (ATRS) World Conference*. 2008: Athens, Greece.

[2] Forrey, P., *Airline Delays and Consumer Issues*, in *Testimony before the House of Transportation and Infrastructure Subcommittee on Aviation*. 2007.

[3] Peterson, M.D., D.J. Bertsimas, and A.R. Odoni, *Models and Algorithms for Transient Queuing Congestion at Airports.* Management Science, 1995. **41**: p. 1279-1295.

[4] Liu, Y. and S. Ma, *The Multimode Estimation Modeling for Flight Delay of A Busy Hub-Airport in Flight Chain*, in *IITA International Conference on Services Science, Management and Engineering*. 2009: Zhangjiajie, China.

[5] Arguello, M.F. and J.F. Bard, *A GRASP for Aircraft Routing in Response to Groundings and Delays.* Journal of Combinatorial Optimization, 1997. **5**: p. 211-228.

[6] Mueller, E.R. and G.B. Chatterji, *Analysis of Aircraft Arrival and Departure Delay Characteristics*, in *AIAA's* Aircraft *Technology, Integration and Operations*. 2002: Los Angeles, USA.

[7] Schaar, D. and L. Sheery, *Performance of the Air Transportation System for the Atlanta-Chicago O'Hare Route*, in *25th Digital Avionics Systems Conference*. 2006: Portland, USA.