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FLIGHT SCHEDULE PUNCTUALITY CONTROL AND MANAGEMENT: A STOCHASTIC APPROACH

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The insufficiency of infrastructure capacity in an air transport system is usually blamed for poor punctuality performance when implementing flight schedules. However, investigations have revealed that ground operations of airlines have become the second major cause of flight delay at airports. A stochastic approach is used in this paper to model the operation of aircraft turnaround and the departure punctuality of a turnaround aircraft at an airport. The aircraft turnaround model is then used to investigate the punctuality problem of turnaround aircraft. Model results reveal that the departure punctuality of a turnaround aircraft is influenced by the length of scheduled turnaround time, the arrival punctuality of inbound aircraft as well as the operational efficiency of aircraft ground services. The aircraft turnaround model proposed is then employed to evaluate the endogenous schedule punctuality of two turnaround aircraft. Model results, when compared with observation data, show that the operational efficiency of aircraft ground services varies among turnarounds. Hence, it is recommended that the improvement of departure punctuality of turnaround aircraft may be achieved from two approaches: airline scheduling control and the management of operational efficiency of aircraft ground services.

Keywords: Airlines; Airports; Aircraft operations; Schedule punctuality; Stochastic models

1. INTRODUCTION

Poor schedule punctuality costs passengers, airports and airlines a considerable amount of money. The insufficiency of infrastructure

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capacity, which includes airport and airspace capacity, is usually blamed for poor schedule punctuality in the air transport system when implementing flight schedules. However, a rigorous investigation into the punctuality issue at London Gatwick Airport revealed that airport and air traffic control (ATC) related reasons were responsible for 53% of total delayed flights [1]. The other delay causes resulted from poor airline services and aircraft ground operations at airports. 61% of flights delayed by airline operations resulted in more than 20 minutes delay, while only 39% of flights were delayed by more than 20 minutes due to airport and ATC reasons during the period of investigation. A confidential review paper available to the authors from a European air carrier also drew similar conclusions as those in the report by the European Civil Aviation Community (ECAC).

After understanding the causes of poor punctuality in the air transport system, airlines such as Lufthansa and Austrian Airlines have task-force projects to improve schedule punctuality [2]. It is generally realized in the airline industry that good management of aircraft rotation improves the punctuality of flight schedules and also saves delay-related costs of airlines. Although hard evidence is not available from the industry, it is generally believed that good control of aircraft turnaround operation and aircraft rotational strategies maintain the competitive edge of low-cost airlines in the European aviation market [3].

The flight schedule punctuality problem has generally been approached in the literature by conventional statistic analyses, which can only provide basic information about punctuality instead of reasons why aircraft are delayed ([4]). It is hypothesized in this paper that the endogenous schedule punctuality has been set after a flight schedule is designed by an airline. In other words, the hypothesis is that it is feasible for an airline to manage schedule punctuality by optimizing its flight schedules and utilizing available resources.

It is apparent from the literature that the aircraft turnaround problem has been mainly investigated using the Critical Path Method (CPM) [5]. This method is usually employed to study an operational procedure consisting of several work flows in order to identify critical paths in the operation. Hence, CPM is commonly used by airlines to investigate the turnaround procedure of aircraft because of the complexity of the aircraft turnaround operation. In addition to CPM, stochastic models have also been developed to model the uncertainty of aircraft punctuality performance and airport gate occupancy time

[6]. However, the stochastic model proposed in the literature captures only the stochastic effects from arrival punctuality of inbound aircraft without considering possible influences of operational disruptions on the aircraft turnaround process.

The aim of this paper is to approach the flight schedule punctuality problem from a more complete stochastic point of view. Stochastic theories are used to model the departure punctuality of a turnaround aircraft to account for uncertainties involved in the implementation of flight schedules. The aircraft turnaround process is simulated by a turnaround model to represent the operational efficiency of aircraft ground services. The turnaround model is then used to evaluate the departure punctuality of turnaround aircraft under current flight schedules. Operational strategies of schedule punctuality management are discussed in this paper in two aspects, namely airline scheduling control and the management of operational efficiency of aircraft ground services. Two case studies are carried out using flight data from a European airline to demonstrate the effectiveness of the aircraft turnaround model.

The paper is organized into six sections. The aircraft turnaround model is described succinctly in Section 2. The application of the turnaround model is given in Section 3, Model Applications. Case studies are given in Section 4, and discussions of schedule punctuality management are shown in Section 5, Strategies for Punctuality Management. Concluding remarks are drawn in the final section.

2. AIRCRAFT TURNAROUND MODEL

2.1. Definitions and Terminology of Aircraft Turnaround

The ‘turnaround’ of an aircraft at an airport gate is defined as the procedure to provide required services (such as catering, cabin cleaning and fuelling) to an aircraft in order to carry out a following flight to another airport. Delays measured in this paper are based on the scheduled time of arrival (STA), i.e., the on-chock time, and the scheduled time of departure (STD), i.e. the off-chock time, of a turnaround aircraft. The duration between STA and STD is defined as the ‘scheduled ground time/scheduled turnaround time’ (denoted by T_{SG} in equation (1)) which consists of the ‘standard aircraft ground service time’ (denoted by T_G) and the ‘schedule buffer time’ (denoted by T) as shown in equation (2). The schedule buffer time in the ground time of a turnaround aircraft is usually designed to accommodate potential delays from late inbound aircraft and delays from aircraft turnaround operation. 'Ground services' of an aircraft include all necessary services, e.g., cabin cleaning, engineering check, aircraft fuelling, for an aircraft to carry out a following flight [7].

$$STD = STA + T_{SG} \tag{1}$$

$$T_{SG} = T + T_G \tag{2}$$

2.2. Aircraft Turnaround Model

A mathematical model is developed in this paper to simulate aircraft turnaround operations. The aircraft turnaround model is based on the formulation of the stochastic departure punctuality of a turnaround aircraft in terms of schedule buffer time (T) and the operational efficiency of aircraft ground services (m_2). The objective of this model is to minimize system costs (C_T), which include passenger delay costs (C_P), aircraft delay costs (C_A) and the schedule time cost of an airline (C_{AL}). A longer ground time for a turnaround aircraft maintains the required punctuality for a turnaround aircraft, though it reduces the productivity of an aircraft. The dilemma between schedule punctuality and aircraft productivity faced by an airline is modelled in the proposed turnaround model by a weight factor, α. The formulation of the aircraft turnaround model is summarized by equations (3) to (10) [8].

To minimize C_T:

$$C_T = \alpha C_D + (1 - \alpha) C_{AL} \tag{3}$$

where

$$0 \leq \alpha \leq 1 \tag{4}$$

$$C_D = E[C_u(s)] = \int C_u(s) g(s) ds \tag{5}$$

$$C_u(s) = C_p(s) + C_A(s) \tag{6}$$

$$C_{AL}(T) = \int C_{AL}^{m}(T - T_A) dT \tag{7}$$

$$g(s) = F[f(t),\ T,\ m_2]^* |J_s| \tag{8}$$

$$s = m_1^*(t - T_A) \qquad T_A \leq t \leq T \tag{9}$$

$$s = m_1^*(T - T_A) + m_2^*(t - T) \qquad T < t \leq T_{\max} \tag{10}$$

where $m_1 = (m_2/T_{\max} - T_A)^*(T_{\max} - T) \qquad T_A \leq T \leq T_{\max}$

The objective function in equation (3) is formulated to minimize the system cost of a turnaround aircraft, which includes the expected delay cost of an aircraft and on-board passengers (denoted by C_D) and the opportunity cost of schedule buffer time of an aircraft (denoted by C_{AL}). The delay cost functions of passengers (C_P in equation (6)) and the delay cost of an aircraft (C_A in equation (6)) are both assumed to be linear with respect to delay duration (s), though more general forms may be used in this model. It is generally realized that the schedule time opportunity cost becomes higher when the saved schedule time becomes long enough for an aircraft to carry out an additional flight. Hence, the airline schedule time cost $C_{AL}(T)$ in equation (7) is assumed to have a linear marginal cost function to account for an increasing opportunity cost when the schedule buffer time of a turnaround aircraft increases and consequently $C_{AL}(T)$ becomes a quadratic function of buffer time, (T).

The first term (denoted by C_D in equation (3)) in the objective function calculates the expected delay cost of a delayed aircraft and on-board passengers by using a probabilistic density function (PDF) of a departure aircraft (denoted by $g(s)$) as shown in equation (8). The departure time (denoted by s in equation (9) and (10)) of a turnaround aircraft is formulated as a function of schedule buffer time (T) and the operational efficiency of aircraft ground services (m_2). The Operational efficiency of aircraft ground services, which is denoted by m_1/m_2 in equation (9) and (10), is modelled by a step-wise linear function to account for the delay absorption effects of the scheduled buffer time in the ground time of a turnaround aircraft. The second term (denoted by C_{AL} in equation (3)) in the objective function estimates the cost of implementing schedule buffer time in the ground time of a turnaround aircraft. The weight factor, α, in equation (3) is used to explain the trade-off condition by balancing the cost of delays and the cost of schedule time.

The value of the unit delay cost of a passenger ($C_p(s)$ in equation (6)) used in case studies is US$0.9/min, which is equivalent to a delay cost of US$54 per hour, per passenger [9]. The value of the unit delay cost of an aircraft ($C_A(s)$ in equation (6)) is US$45/min for ground delays, which is equivalent to a delay cost of US$2,700 per hour per aircraft (in this case a Boeing 757). The opportunity cost of schedule buffer time (C_{AL}^{m} in equation (7)) is US$2.5/min, which is equivalent to US$4,500 per hour for a European short-haul route. Equal weights, i.e. $\alpha = 0.5$, on the delay cost of passengers and the airline schedule time cost are used in the following numerical analyses.

3. MODEL APPLICATIONS

3.1. Schedule Control – The Use of Schedule Buffer Time

Beta functions are chosen to model the PDF of inbound aircraft (*f*(t) in equation (8)) because of its analytical tractability in mathematical modelling. The PDF of a departing turnaround aircraft (*g(s)* in equation (8)) is determined by its corresponding arrival time of inbound aircraft (*f(t)*), schedule buffer time (*T*) in the ground time of a turnaround aircraft, and the operational efficiency of aircraft ground services (m_2) formulated in equation (9) and (10). For instance, Beta(10,3) distribution is used to model the arrival pattern of Flight_A which has 20% on-time arrivals and 99% of flights arriving within 20-minute delay. The corresponding departure PDFs (*g(s)*) of Flight_A are shown in Figure 1. It is observed from Figure 1 that the more schedule buffer time is scheduled in the ground time of Flight_A, the more punctual turnaround departure flights will be. The maximum schedule buffer time (T_{max} in equation (10)) for Flight_A is 20 minutes, as it is long enough to include 99% of arrivals within buffer limits in this case.

However, it might be argued that the shape of aircraft arrival time PDFs could be centrally distributed. Hence, a further analysis was conducted to investigate the influence of shapes of quasi-normal distributions on model outputs. Three centrally distributed PDFs,

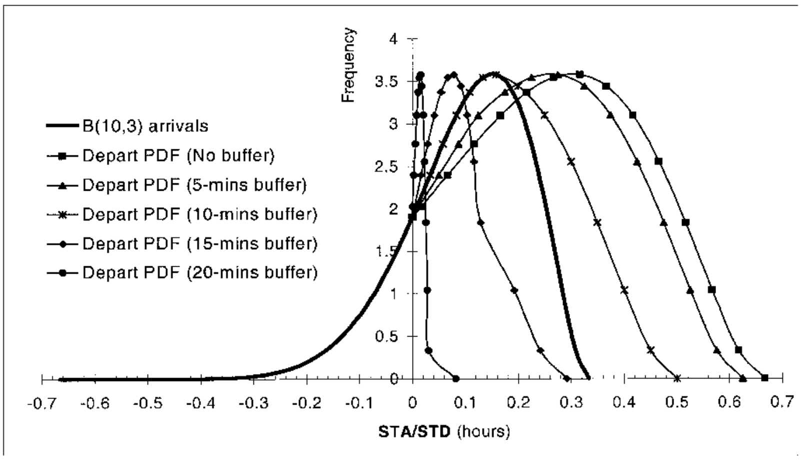

FIGURE 1 Departure PDFs corresponding to different punctuality buffer time.

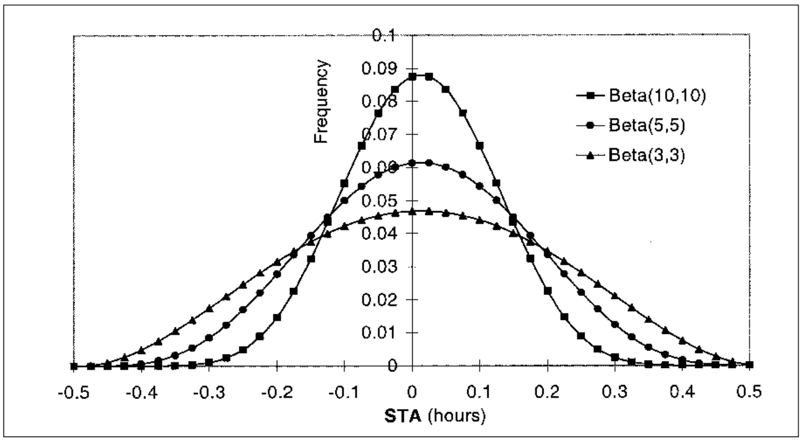

FIGURE 2 PDFs of Beta(10,10), Beta(5,5) and Beta(3,3) functions.

Beta(3,3), Beta(5,5) and Beta(10,10) were used to test the aircraft turnaround model. The illustration of PDFs of these Beta functions is given in Figure 2. The STA of these cases is set at zero hour in the range between -0.5 and 0.5 hour, so the arrival punctuality in all three cases is 50%. The model outputs of three flights are shown in Figure 3. It is found that the shape difference of PDFs causes a change in the expected delay cost, C_D (illustrated by dotted lines) and consequently a change of total system cost, C_T (illustrated by hashed lines). The schedule time cost, C_{AL} remains the same for all three cases, as these flights are operated by the same airline. Hence, the optimal schedule buffer time is found to be 15, 15 and 10 minutes for the case of Beta(3,3), Beta(5,5) and Beta(10,10) respectively when the system cost has its minimum.

It is seen in Figure 3 that the total system cost of the Beta(3,3) case is the highest among the three cases. The high system cost of the Beta(3,3) case is contributed by the high expected delay cost because of the shape of Beta(3,3) functions. It is seen in Table I that three PDFs have the same mean value of 0.5 but have different standard deviation. Beta(3,3) has the highest standard deviation which results in the 'flatter' shape of Beta(3,3) as illustrated in Figure 2. As a result, the arrival CDFs of three cases differ from each other as shown in Figure 4. It can be seen in Figure 4 that it takes 0.15, 0.2 and 0.25 hours of delay for Beta(10,10), Beta(5,5) and Beta(3,3) case respectively to achieve the cumulative arrival punctuality of 90%. Hence, the expected delay cost of the Beta(3,3) case is higher than the other two

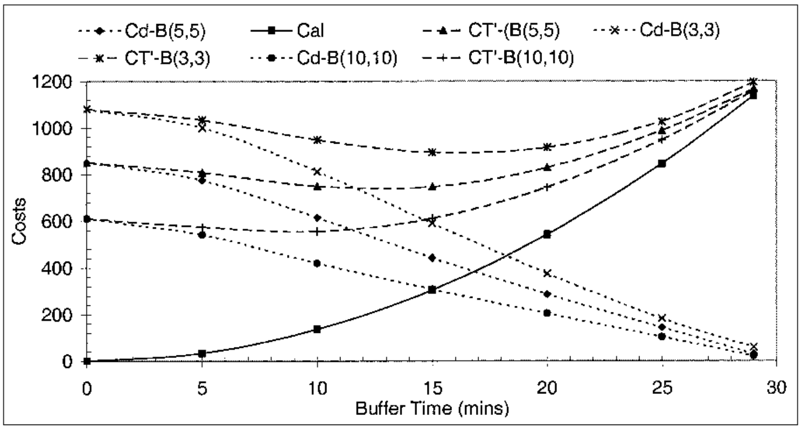

FIGURE 3 Influence of aircraft arrival PDFs on model outputs.

cases. Therefore, it is found from the previous discussion that the arrival pattern of inbound aircraft influences the optimal use of schedule buffer time through the expected delay of inbound aircraft, i.e. the arrival punctuality of inbound aircraft, instead of the shape of PDFs of inbound aircraft.

3.2. Influence of Arrival Punctuality of Inbound Aircraft on Aircraft Turnaround Punctuality

It is realized from empirical punctuality analysis that arrival aircraft exhibit different punctuality patterns, which might result from enroute

TABLE I Descriptive statistics of chosen Beta functions

	Mean[a]	*Median*	*Standard deviation*
Beta(10,10)	0.5	0.5	0.14
Beta(5,5)	0.5	0.5	0.18
Beta(3,3)	0.5	0.5	0.21

[a] The range of the independent variable in this case is between 0 and 1.

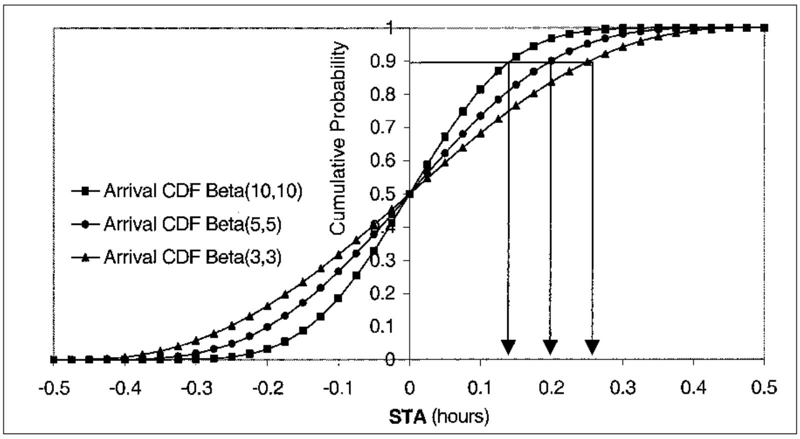

FIGURE 4 CDFs of Beta(10,10), Beta(5,5) and Beta(3,3) functions.

airspace congestion and aircraft turnaround delays at outstations [8]. It is also found from empirical analysis in relevant literature that the departure punctuality of a turnaround aircraft is related to the arrival punctuality of inbound aircraft [6]. However, the uncertainties in aircraft turnaround operation were not included in previous research. Hence, it is of interest in this paper to investigate how the relationship develops between the arrival punctuality and the departure punctuality of a turnaround aircraft when considering the operational efficiency of aircraft turnarounds.

For instance, Flight_A of Airline R in Figure 5 exhibits an arrival pattern of Beta(10,3) with a STA time of 40 minutes within an arrival time domain of 60 minutes, i.e. 99% of flights arrive with the maximum arrival delay of 20 minutes. A similar arrival time distribution is observed from Flight_B but with a STA time of 30 minutes, i.e. worse arrival punctuality. The simulated departure PDFs of these two flights are shown in Figure 5. It is seen that Flight_B incurs longer departure delay than Flight_A under the same arrival pattern but different arrival punctuality of inbound aircraft. Therefore, it is found that the departure punctuality of a turnaround aircraft is sensitive to the arrival punctuality of inbound aircraft.

Since different punctuality performance is observed from different routes, the improvement of gate-to-gate punctuality in the air transport system relies on scheduling strategies and turnaround operational efficiency of an airline. As seen in Figure 5, the arrival punctuality of inbound aircraft influences the departure punctuality of a turnaround

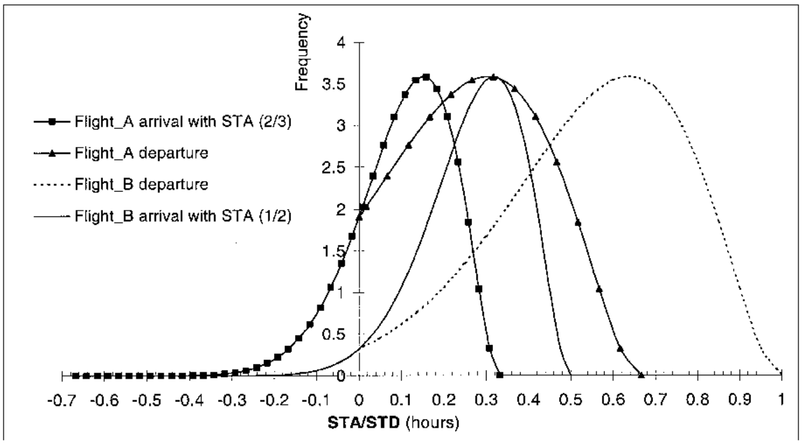

FIGURE 5 Influence of arrival punctuality of inbound aircraft on departure PDFs.

aircraft. As a consequence, different schedule buffer time should be applied to different flights in order to maintain a consistent schedule punctuality. Flight_B, in this example needs a longer buffer time than Flight_A due to the latter's better arrival punctuality. The implication of this example is that aircraft operations at outstation stops also play an important role in the improvement of schedule punctuality of turnaround aircraft at an airport as well as the schedule reliability of aircraft rotations between airports. Operational improvements are generally undertaken at a single airport to improve the performance of schedule delivery. However, it is found in this example that improvements at a single airport do not necessarily achieve the system optimum, unless the system is optimized on a network scale.

3.3. Aircraft Ground Services

The scheduled ground time of an aircraft is designed to accommodate the service time of aircraft turnaround and potential delays from inbound aircraft as well as delays from aircraft turnaround operations. The arrival delay of an aircraft causes a late start of aircraft ground services and is likely to result in a late finish of aircraft turnaround. As a consequence, the scheduling of equipment and staff of ground services is influenced. The most serious influence of ground service disruption is the knock-on effect of disruptions to stand plans of the other aircraft on the ground waiting for services. When the arrival delay of a turnaround aircraft disturbs stand plans of airport gates, departure delay will probably happen and even deteriorate during turnaround operations if the operation of aircraft turnaround is not well managed. To further explain this situation, the operational efficiency of aircraft ground services is described in the aircraft turnaround model by a stochastic variable, m_2 in equation (9) and (10). When the schedule perturbation is not sufficiently significant to disturb turnaround operations and the ground handling agent is able to control service time, m_2 is assigned a value which is equal to or less than unity in equation (9), i.e., no further delays result from turnaround disruptions in this case. Hence, a higher value of m_2 means that departure delay of a turnaround aircraft is contributed partially by the arrival delay of inbound aircraft and partially by the operational delay from aircraft turnaround.

To investigate the influence of ground service efficiency on aircraft turnaround punctuality, a numerical study was carried out in this paper by simulating a turnaround aircraft which shows Beta(10,3) arrival punctuality with a STA of zero hour within an arrival time domain between -0.5 and 0.5 and 10 minutes schedule buffer time. It is seen in Figure 6 that if schedule disturbance from arrival delay is significant to aircraft ground services (in this case, m_2 is 2), the departure PDF of turnaround aircraft (illustrated by the dotted line in Figure 6) exhibits a longer right tail. On the other hand, when the better management of

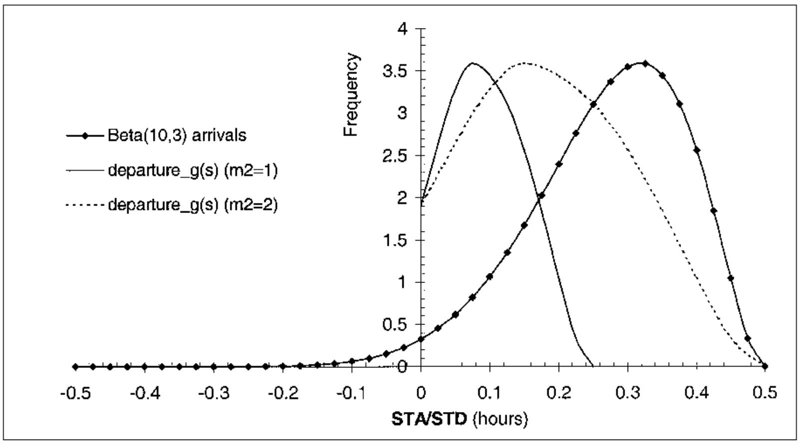

FIGURE 6 Influence of ground service efficiency on departure punctuality of a turnaround aircraft.

turnaround services can be achieved by operational means [9], the departure delay of the turnaround aircraft becomes less and the right tail of the departure PDF becomes shorter (represented by the solid line in Figure 6). Therefore, it is found that the efficiency of aircraft turnaround operation significantly influences the departure punctuality of turnaround aircraft. Evidence from the air transport industry also revealed that low-cost airlines in Europe reduce operational costs through minimizing aircraft turnaround time on the ground and maximizing aircraft turnaround efficiency at hub airports to increase aircraft productivity [3].

4. CASE STUDIES

Two case studies were carried out to demonstrate the effectiveness of the aircraft turnaround model proposed above. Flight data collected in the summer of 1999 from a European airline, Airline R, were used in these case studies. Flight data represent three-month operations of two typical European city-pair flights RR-X and RR-Y which were turned around at the base airport of Airline R. RR-X was scheduled to arrive at 18.45 hours and to depart at 19.45 hours. RR-Y was scheduled to arrive at 16.30 hours and to leave at 17.35 hours. A Boeing 757 aircraft was used to carry out these two flights during operations in 1999. Arrival PDFs of these two flights are statistically fitted from flight data as shown in Figure 7. Both PDFs past the *K-S Goodness of Fit Test* as shown in Table II and therefore, were used to simulate arrival punctuality of these two flights. There were 55% punctual flights for RR-X and 60% for RR-Y.

The aircraft turnaround model was applied to simulate the turnaround operation of RR-X as well as the departure punctuality of RR-X. The CDFs of departure punctuality of RR-X from model results are shown in Figure 8. Different lengths of schedule buffer time were applied in the turnaround model of RR-X and it resulted in different expected departure CDFs. It is seen from Figure 8 that the longer the buffer time is scheduled in the turnaround time of RR-X, the more punctual departure flights will be. The observed departure punctuality of RR-X is illustrated in Figure 8 by a thick solid line. It is seen in Figure 8 that the observed departure punctuality of RR-X is close to the estimated departure CDF having a schedule buffer time set at 0.7 hours with respect to the STA of 1/3, i.e., about 20 minutes schedule buffer time in this case.

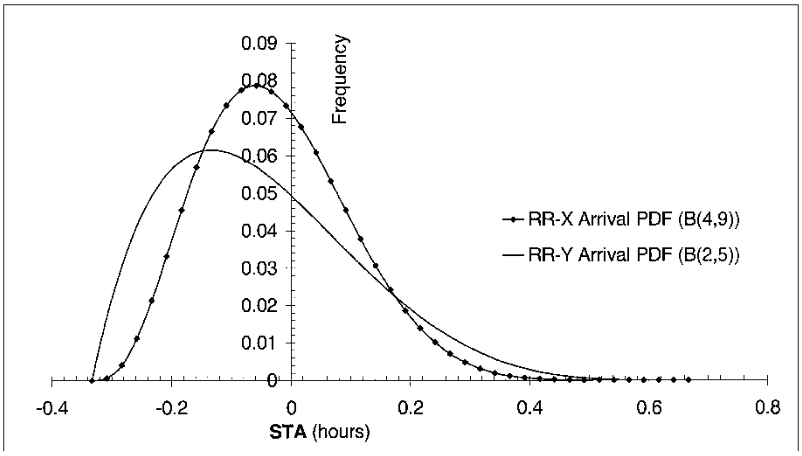

FIGURE 7 Arrival PDFs of RR-X and RR-Y.

TABLE II K-S test of fitted arrival PDFs of RR-X and RR-Y

	PDF	*K-S test value*	*Sample size*	*Significant K-S value*	*Goodness of fit*
RR-X	Beta(4,9)	0.0528	51	0.1679	Yes
RR-Y	Beta(2,5)	0.1042	82	0.1331	Yes

The scheduled ground time of RR-X was 60 minutes and consequently the schedule buffer time was about 20 minutes when turning around the Boeing 757 aircraft. Compared with model results, the observed turnaround punctuality of RR-X is found to be commensurate with the 20-minute buffer time. However, it is also found in Figure 8 that the observed cumulative departure punctuality of RR-X is relatively better within short departure delays (5 minutes) than model results and is relatively worse than model results in some departures which have longer departure delays (more than 20 minutes). It is found from observations of aircraft turnarounds by Airline R that longer delays to turnaround aircraft resulted from longer arrival delays of inbound aircraft as well as from delays due to disruptions to aircraft turnaround operations. As a consequence, a thicker right tail is found in observed departure punctuality CDF of RR-X due to some extreme cases in observations. It is also realized that the proposed aircraft turnaround model is not good at modeling extreme cases, i.e. inbound

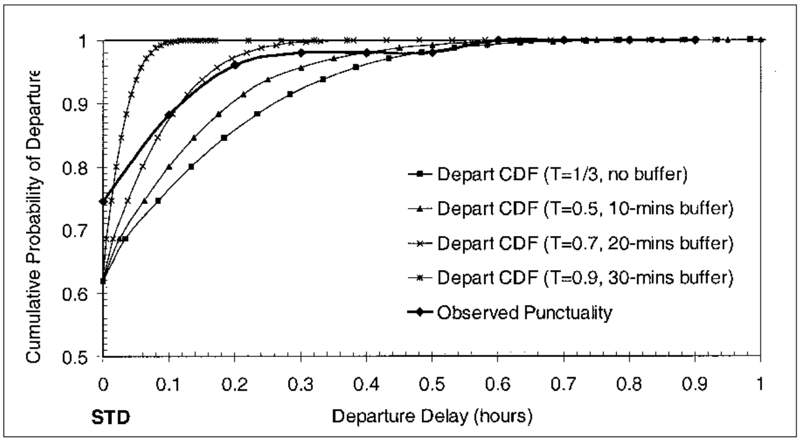

FIGURE 8 Departure punctuality of RR-X from observations and simulations.

aircraft with very long arrival delays, by using an aggregate model because futher departure delays might result from stand plan disruptions.

The second case study was undertaken by applying RR-Y's flight data to the turnaround model. The comparison between observed departure punctuality from Airline R and estimated departure CDFs of RR-Y are shown in Figure 9. The observed departure CDF of RR-Y (represented by a thick solid line) develops closely to the estimated CDF having a schedule buffer time set at 1/3 with respect to the STA of 1/3, i.e., no buffer time included in this case. From the given flight schedule of RR-Y, it is known that the scheduled ground time of RR-Y was 65 minutes which included 25 minutes buffer time when turning around a Boeing 757 aircraft. Model results show that 25-minute buffer time ought to be long enough to include 95% of delayed arrivals. However, it is seen from Figure 9 that the turnaround punctuality of RR-Y was not commensurate with the amount of buffer time in RR-Y's schedule. In other words, the implemented schedule punctuality of RR-Y did not match the endogenous punctuality requirement in RR-Y's schedule.

5. STRATEGIES FOR PUNCTUALITY MANAGEMENT

A hypothesis made earlier in this paper is that the endogenous schedule punctuality has been set after a flight schedule is chosen by

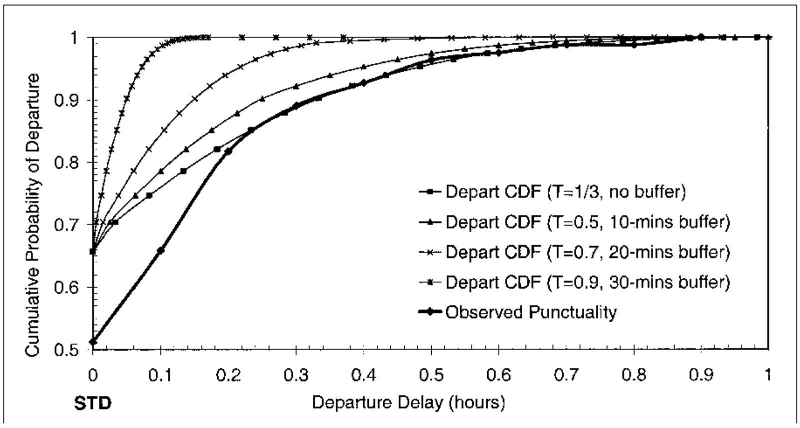

FIGURE 9 Departure punctuality of RR-Y from observations and simulations.

an airline. In other words, the hypothesis states that it is feasible for an airline to manage its schedule punctuality by changing its flight schedules. As demonstrated in the case studies, RR-X exhibits good turnaround punctuality with respect to its scheduled turnaround time as shown in Figure 8. On the other hand, the turnaround punctuality of RR-Y (illustrated in Figure 9) matches the estimated departure CDF which includes no schedule buffer time, despite actually having a buffer of 25 minutes for the turnaround. It is found from case studies that the turnaround time of RR-Y was not long enough to absorb potential delays from inbound aircraft as well as delays from aircraft turnaround operations. Yet the endogenous schedule punctuality of a turnaround aircraft can be achieved by good management of turnaround operations such as flight RR-X. Hence, the schedule punctuality of RR-X is expected to be as good as it is to commensurate with the amount of schedule buffer time included in its schedule.

It is usually argued by airlines that flight delays are mainly caused by uncontrollable factors such as air traffic flow management, passenger boarding delays, inclement weather and so forth. However, cases like flight RR-Y are not unusual for airlines and passengers. The case study of RR-Y offers airlines some clues towards the better management of schedule punctuality. Managerial strategies to improve schedule punctuality of turnaround aircraft are therefore, recommended to focus on two aspects: airline scheduling control and the management of operational efficiency of aircraft ground services.

It is feasible for an airline to manage schedule punctuality by optimally scheduling flights. For instance, flight RR-Y did not achieve its endogenous punctuality performance, even though 25 minutes of buffer time has been scheduled in the turnaround time. Airline R, therefore, can improve RR-Y's departure punctuality by scheduling longer turnaround time at the airport, if a longer ground time is needed. In addition, the improvement of the arrival punctuality of inbound aircraft of RR-Y can also help improve turnaround punctuality of RR-Y at the study airport. As a result, the departure punctuality of RR-Y can be improved by optimizing scheduling control at the base airport and outstations.

The management of schedule punctuality can also be achieved by the improvement of operational efficiency of aircraft turnaround. It has been demonstrated previously in this paper how significantly the departure punctuality of a turnaround aircraft is affected by the efficiency of aircraft ground services. Although short aircraft turnaround time increases the productivity of aircraft, it also risks airlines and passengers suffering delays because of a lack of delay absorption ability in a tight turnaround schedule. On the other hand, the operation of aircraft ground services should be able to absorb operational delays to aircraft turnaround by operational means when delays are about to happen [5, 9, 10]. Most low-cost airlines in Europe operate tight aircraft turnaround schedules at their base airports because the operational efficiency of aircraft turnaround can be fully controlled and managed by these airlines. Maintaining the efficiency of aircraft turnaround is believed to be the key factor for low-cost airlines to deliver a reliable schedule of aircraft rotations [3]. However, there is still some potential risks for airlines operating tight aircraft turnaround and rotational schedules. When schedule irregularities occur, the most likely solution to elimilate knock-on delays in intensive aircraft rotation schedules is to cancel flights.

6. CONCLUSIONS

A stochastic approach was used in this paper to model the operation of aircraft turnaround and the departure punctuality of a turnaround aircraft at an airport. The aircraft turnaround model was then used to investigate the punctuality problem of turnaround aircraft. Model results revealed that the departure punctuality of a turnaround aircraft is influenced by the length of scheduled turnaround time, the arrival punctuality of inbound aircraft as well as the operational efficiency of aircraft ground services. The proposed aircraft turnaround model was also employed to evaluate the endogenous schedule punctuality of two turnaround aircraft. Model results, when compared with observation data, showed that the operational efficiency of aircraft ground services varies among turnarounds. As a consequence, the departure punctuality of some turnaround aircraft matches the endogenous schedule punctuality, but some others do not.

Therefore, it is recommended that the improvement of departure punctuality of turnaround aircraft may be achieved from two approaches: airline scheduling control and the management of operational efficiency of aircraft ground services. It is also realized that the departure punctuality of a turnaround aircraft is influenced significantly by the arrival punctuality of inbound aircraft. Arrival delays of inbound aircraft not only consume the scheduled turnaround time of an aircraft, but also disturb stand plans of an airport and might lead to a longer aircraft ground service time than scheduled. Therefore, it is suggested that future research focus on the influence of aircraft turnaround operations on the schedule punctuality of aircraft rotation in a network of airports in order to improve the schedule reliability of aircraft rotation on a network scale.

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