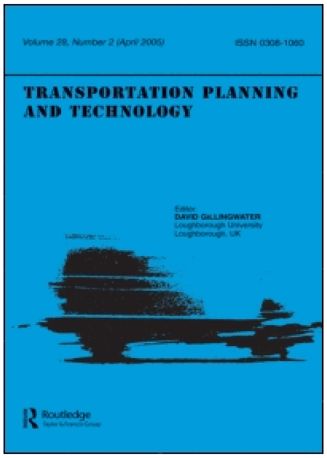

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Monitoring Aircraft Turnaround Operations - Framework Development, Application and Implications for Airline Operations

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ARTICLE

Monitoring Aircraft Turnaround Operations – Framework Development, Application and Implications for Airline Operations

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ABSTRACT A real-time operation monitoring system – Aircraft Turnaround Monitoring System – is developed based on a system framework to monitor aircraft turnaround operations at an airport. Mobile computing devices (PDAs) and wireless network technology General Packet Radio Service (GPRS) are used to implement the real-time monitoring system for an airline. System implementation and test results indicate that real-time operation monitoring can potentially reduce delays occurring from airline operations. Proactive measures can be taken immediately by ground handling staff to reduce delays, once the risk of delays and potential delay propagation is identified. The availability of detailed operating data can help airlines identify the root delay causes from complex connections among aircraft, flight/cabin crew and passengers. In addition, these operating data also shed some light on the future development of aircraft routing algorithms in order to consider explicitly stochastic disruptions and delay propagation in airline schedule planning.

KEY WORDS: Aircraft turnaround; turnaround operation monitoring; delay propagation; delay-coding system; real-time monitoring; mobile technology

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Aircraft Turnaround Operation and Issues

Aircraft turnaround operations refer to the activities conducted to prepare an inbound aircraft for a following outbound flight that is scheduled for the same aircraft. Accordingly, activities of aircraft turnaround operation include both inbound and outbound exchange of passengers, crew, catering services, cargo and baggage handling. Technical activities in turning around an aircraft include fuelling, routine engineering checks and cabin cleaning.

Since passenger numbers and cargo/baggage loads vary from flight to flight, the realised turnaround time of an aircraft is stochastic in nature. The scheduled turnaround time of an aircraft is defined as the time duration between the on-block and off-block time of the aircraft at a gate. Transfer traffic may occur at airports during the aircraft turnaround times such as flight/cabin crew, passengers and cargo/ baggage. Under the complex resources connection mechanism among aircraft, passengers and crew, disruptions may occur to any processes of aircraft turnaround and may consequently cause delays to departure flights. Disruptions such as connecting passengers, connecting crew, missing check-in passengers, late inbound cargo/baggage or equipment breakdown are normally seen in daily airline operations.

While disruptions caused by air transport system capacity reduction attract much attention mostly because of its large scale of impact (c.f. Arguello *et al.*, 1998; Barnhart *et al.*, 1998; Luo & Yu, 1997; Rexing *et al.*, 2000; Teodorovic & Stojkovic, 1995; Yan & Young, 1996), it is interesting to know that disruptions within this category account for roughly 40–50% flight delays in Europe including those caused by weather (Eurocontrol, 2004, 2005). Other delay causes (the remaining 50–60%) are attributed to airline operations and scheduling in which reactionary delays may account for up to 20–30% of the 50–60% delay share; technical faults may account for up to 10% (Eurocontrol, 2004, 2005). Delays cost money for airlines and passengers, no matter where the delays come from. While some efforts have been put in searching for the optimal strategies to recover from schedule disruptions due to major system capacity reduction, less attention has been focused on exploring how delays caused by airline operations can be reduced and minimised.

Low-cost carriers know it very well how a fast and reliable turnaround operation can improve the bottom line of airline operations and profitability through high utilisation of aircraft and low exposure to unexpected delays. Since delays may occur to any processes of schedule execution, buffer times are usually designed in flight schedules to accommodate unexpected disruptions and any consequent delays. Buffer times may be placed in the block times of flights as well as in the ground times for aircraft turnaround operations. Since airlines have more control, power and flexibility over the turnaround processes on the ground, the scheduled ground times for turnarounds are seen as a tactical and effective means to stabilise aircraft rotations and to prevent further knock-on delays (also called reactionary delays or delay propagation) down the rotation lines of the whole fleet. Given the resources/passengers exchange behaviour among flights, disruptions to some resources/activities may cause delay propagation in the network via aircraft rotation, unless delays are effectively contained by tactical measures or absorbed by the buffer times designed in the schedule. Hence, one can realise the crucial role played by maintaining efficient and effective aircraft turnaround operations in daily airline operations control.

Managing Turnaround Operations

The typical approach to manage aircraft turnaround operations is to apply standard operating procedures (SOP), which are usually developed by aircraft manufacturers and modified by individual airlines to suit local operational needs. Gantt charts of aircraft turnaround 'SOP' are hence widely used in the airline industry. Figure 1 shows a B737 precision timing schedule (PTS) adopted by an Australian carrier for domestic turnaround operations in Australia. The standard aircraft turnaround PTS benchmarks all processes against the scheduled departure time of a flight as shown in Figure 1. All processes are required to be finished by the 'latest finish times' to prevent causing

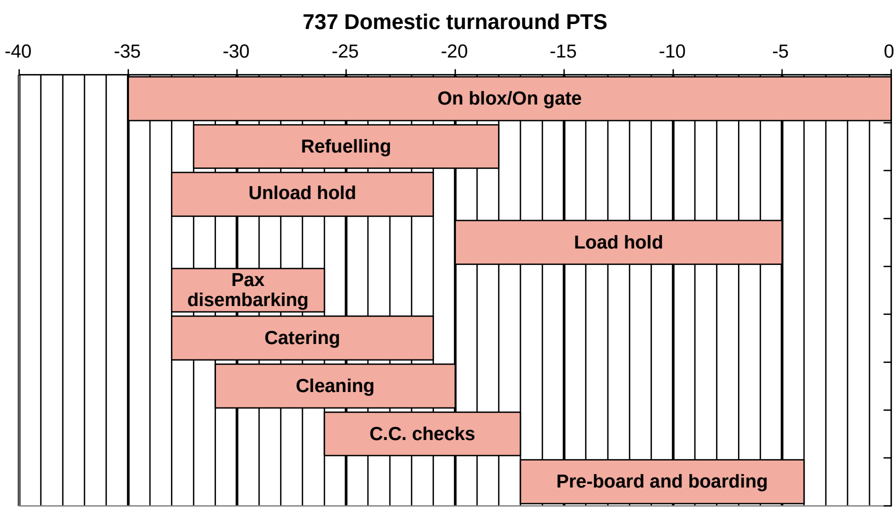

Figure 1. Boeing B737 PTS for domestic operations in Australia

knock-on delays on following processes. Critical path analysis is hence widely used by airlines to identify potential critical paths in turnaround operations (Abdelghany *et al.*, 2004; Braaksma & Shortreed, 1971; Hassounah & Steuart, 1993).

Since activities in aircraft turnarounds present certain characteristics such as grouped processes and sequential work flows, the prevailing strategy to conduct ground handling is to assign individual flows to different operating units, e.g. catering unit, baggage/cargo handling unit and passenger handling unit. This ground handling strategy has the most benefits when the strategy is adopted by a home-base carrier or a third-party ground handling agent to handle the intensive needs of ground handling services. However, the challenge of this strategy is to ensure that good communication and coordination exists among operating units. Some airlines, in particular low-cost carriers, tend to use a 'team strategy' to carry out aircraft turnaround operations. As suggested by the name, turnaround activities are conducted by a turnaround team which is assigned to handle all turnaround activities of an aircraft. Accordingly, the handling team consists of multi-skilled staff including a team leader to ensure communication and coordination is well maintained during the operation. This team strategy requires a higher staffing level than the 'unit strategy', but the operating efficiency and the capability to maintain punctuality and minimise knock-on delays may compensate the higher staffing cost.

Punctuality data are mostly compiled from the 'time stamps' acquired manually by airline staff or automatically through the Aircraft Communication Addressing and Reporting System (ACARS). Time stamps may include the take-off time (wheel off), landing time (wheel on), arrival time (on-block at gates) and departure time (off-block at gates). However, operating data of ground handling, e.g. the catering unloading start time and finish time, are hardly well recorded by airlines for the purpose of operations research. Airlines may have some records of these time stamps, but they are either scattered among different operating units or not collated centrally for operations research. The lack of operating data makes it difficult to evaluate the operating performance of ground handling services and also impossible to calibrate the PTS of different aircraft types at different airports. For airline operations control, the widely available ACARS time stamps are used to track the progress of individual aircraft in daily operations. However, the lack of time stamps during aircraft ground times makes the turnaround operations a 'black box', because it is hard to coordinate available ground resources without turning to frequent radio conversations between operations controllers, airport duty managers and ground handling staff. Given the crucial role played by ground operations in minimising delay propagation in airline networks, it would be of tremendous benefit to airline operations control if operational data are available during ground operations on a real-time basis. This would allow operation controllers to pay precautionary attention to potential events which might delay a departure or potentially cause serious delay propagation in the network. The potential impact of this information on airline operations control is demonstrated by the work of Abdelghany *et al.* (2004) in which flight delays and potential breaks of resources connection are projected ahead of schedule execution.

The objective of this paper is to develop a turnaround monitoring framework which serves as the platform to collect operational data, benchmark turnaround efficiency and calibrate PTS procedures of different aircraft types. Secondly, a real-time monitoring system is developed based on the framework and serves as the real-time data collection tool providing all involving units with high situational awareness and up-to-date progress of aircraft turnarounds. The deployment of the monitoring system is discussed and the implications of the availability of real-time operating information on maintaining schedule operational reliability are further discussed.

Aircraft Turnaround Monitoring System (ATMS)

System Framework Development

An Aircraft Turnaround Monitoring System (ATMS) is developed to collect operating data on a real-time basis during aircraft turnarounds. ATMS is also used to conduct real-time monitoring by utilising collected operating data. Based on the operational needs of individual ground handling units and the functional needs of operations monitoring, an ATMS framework is developed as an open framework as shown in Figure 2, which allows future development of add-on modules based on the same platform and structure. Based on most PTSs of aircraft, turnaround activities are grouped into four major process flows, namely passenger, cargo, engineering check and catering. Activities within each process flow are chosen and included in the framework according to the needs of data collection and the importance of individual activities in turnaround operations. Using this framework, individual handling units only need to collect time stamps of key activities during turnarounds, so the progress of individual process flows can be easily shared between the handlers and the control unit, e.g. catering loading staff and the catering centre. Meanwhile, the collected information during turnaround operations can also be shared among different handling units, the ground operations centre at the airport and the network operation control centre at the carrier's

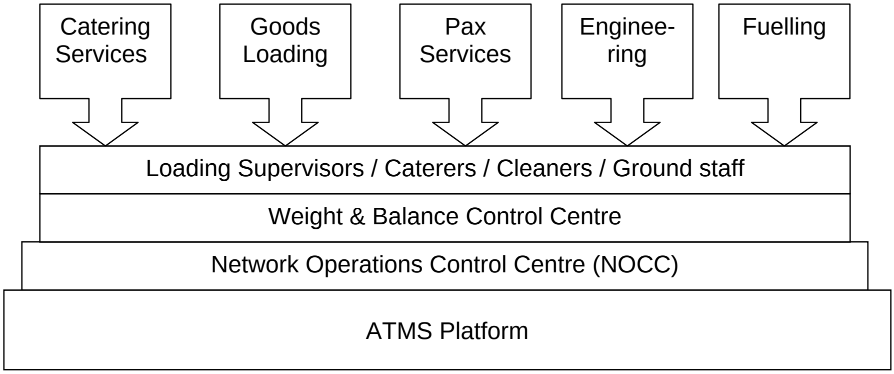

Figure 2. ATMS framework

headquarters. The availability of up-to-date operating information and the transparency of turnaround operations greatly increases the situational awareness of all units involved in aircraft turnaround operations and airline operations control.

A list of key activities chosen in each process flow is given in Table 1. Some activities have an operational sequence to follow such as passenger, cargo and catering flows. Other activities such as refuelling and engineering checks are operated independently from other activities.

Implementation

The ATMS framework is implemented using mobile devices and telecommunication network technology, namely GPRS (a widely used mobile phone network service, which provides Internet access to mobile phone users). Given the environment in which ground handlers work on the apron and to minimise the inconvenience of entering data, Personal Digital Assistants (PDAs) are chosen as the mobile device in this implementation. Activities and flows given in Table 1 are programmed and implemented on a Palm PDA. Collected time stamps are stored locally on the PDA and transmitted immediately through the GPRS network to a remote database server.

The data flowchart of ATMS is shown in Figure 3. Multiple PDAs can be used for a single aircraft turnaround operation, if the ground handling strategy belongs to the 'unit strategy'. If a 'team strategy' is used for ground handling, then the team leader can use one PDA to control and monitor all turnaround activities of an aircraft. An in-house real-time simulation model, namely Turnaround Operation Monitoring Agent (TOM) is connected to the database to monitor the status of multiple turnarounds at different airports (as long as there is live data

Table 1. Activities included in ATMS

Activity no.	Passenger	Cargo	Engineering	Catering
1	Position passenger steps/air bridge	Position cargo loader	Routine maintenance start	Open catering service door
2	Open passenger door	Open cargo door	Routine maintenance finish	Unload carts
3	Disembark passengers	Unload baggage	Fuelling start	Load carts
4	Onboard customs control/crewing	Unload cargo	Fuelling finish	Close door
5	Disembark crew	Load cargo	Wheel and tire check start	
6	Cabin and cockpit cleaning start	Load baggage	Wheel and tire check finish	
7	Final cleaning	Close cargo door		
8	Board crew	Remove cargo loader		
9	Crew check			
10	Board passengers			
11	Close passenger door			
12	Remove passenger steps/air bridge			

input streams available) and updates the estimated departure times of each monitored flight. Operation controllers at the Network Operations Control Centre (NOCC) may receive a warning message from TOM, if the projected departure delay exceeds a predefined delay threshold. Operation controllers can then radio the manager of the ground handling unit to resolve the potential delay or send text messages to the manager via PDAs requesting proactive delay control actions. If the projected delay is long and cannot be speedily resolved, the NOCC controllers have the option to activate the schedule disruption recovery protocol to deal with potential passenger itinerary disruptions, crewing disruptions and aircraft routing irregularities.

Two screen shots of the ATMS implementation on PDAs are given in Figure 4. The main menu of ATMS as shown in Figure 4(a) includes six options: arrival, passenger, cargo, engineering checks, catering and departure. Arrival and departure options record the on-/off-block times of aircraft at gates, which are used as a reference to the ACARS arrival and departure time records. Activities under the ‘passenger’ option are listed on the PDA screen as shown in Figure 4(b). When an activity

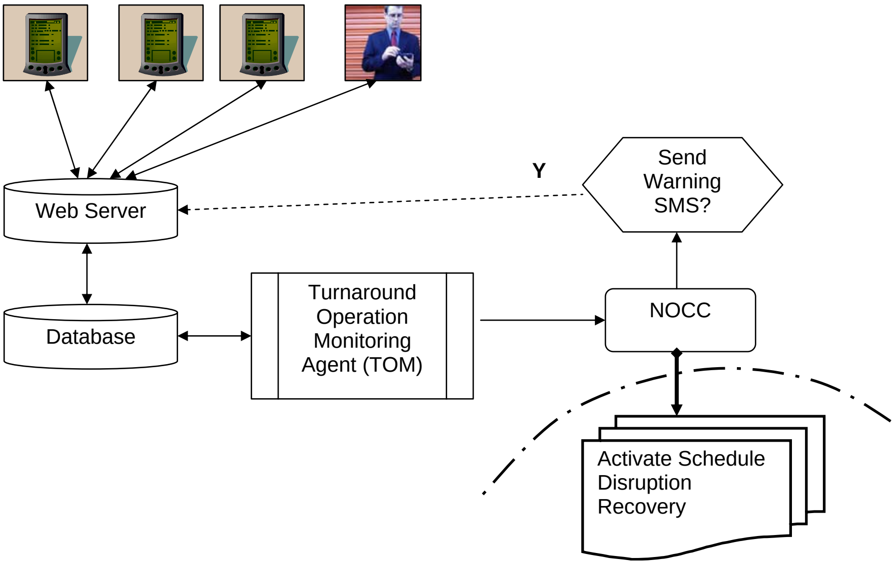

Figure 3. ATMS live data flowchart

starts/finishes, the user only needs to click the activity on the screen. The current time stamp of the corresponding activity will be automatically obtained, stored and transmitted via the GPRS network to the remote database server immediately.

System Tests, Results and Implications

The ATMS system was first tested in April 2005 for communications. Immediately following the test, the first trial was undertaken by Qantas at Sydney Airport to collect ground handling data to benchmark the operational efficiency of their aircraft turnaround services. The second trial took place in January 2006 at Sydney Airport to collect data to improve the PTS of the Boeing B737 family of aircraft. Due to the sensitivity of some collected data during trials, only selected results are given in this paper for the validation of the ATMS framework and its implementation in airline operations.

System Test Results

The catering service is given here as an example of the results because it has caused some operational problems and departure delays in recent domestic operations for Qantas. Figure 5 shows the observed start/finish times of catering services. The reference time in the following analysis is the 'actual time of departure', i.e. the un-block time at gates.

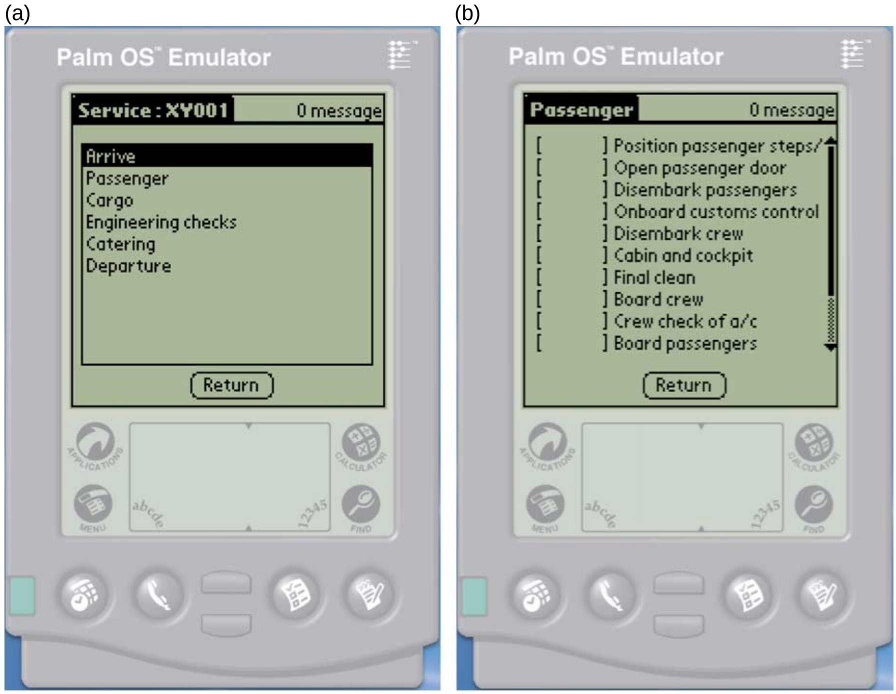

Figure 4. (a) Main menu of ATMS for flight XY001 and (b) input screen for passenger processing flow

Those two bars highlighted with bold lines in Figure 5 represent the standard start/finish times of catering services for the B737, which are 38 and 25 minutes before pushing back the aircraft. We can see from Figure 5 that some catering services start early and this is mostly due to the long scheduled turnaround time and some early arrivals. Scheduled ground times for this sample group range from 45 to 65 minutes. Thirty-two percent of catering services start late and also cause 43% catering services finishing late. The domino effect of this delay is to delay passenger boarding start time and consequently cause departure delays to 20% of the total sampled flights, i.e. 16 out of 56 flights. However, the catering service is not the sole reason causing departure delays to those 16 flights. Among them, six flights are also delayed due to passenger/goods connections between flights at Sydney Airport.

The goods unloading process usually causes little trouble unless the process is delayed due to late equipment or equipment breakdown. The goods loading process, however, may cause delays to turnaround operations, in particular for complex goods connections between flights. Figure 6 shows the observed loading start times and finish

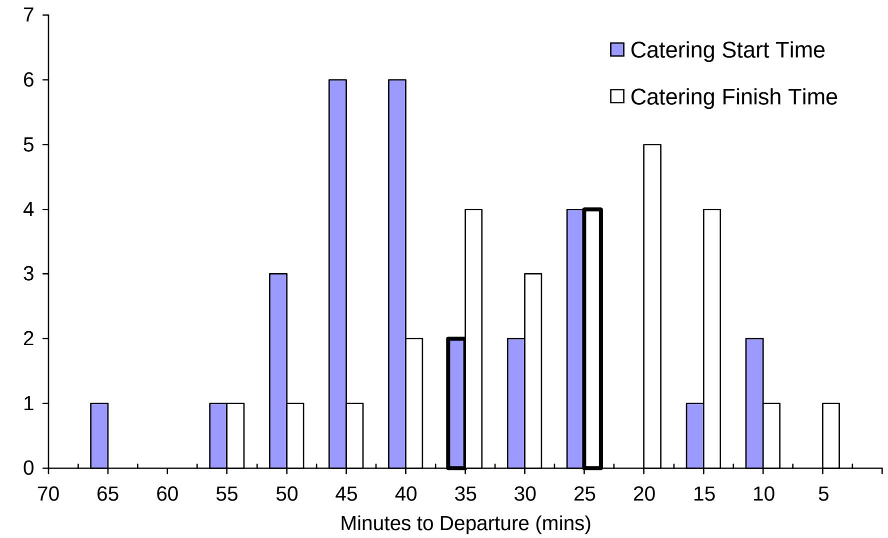

Figure 5. Start and finish times of catering service

times with respect to the actual departure time of flights. It shows 22% flights have late loading starts and this reflects on 17% late loading finish and consequently loading delays. Early loading starts in Figure 6 are due to long turnaround times. Overall, loading-related reasons cause 21% flight delays within sampled flights. Among these 21%

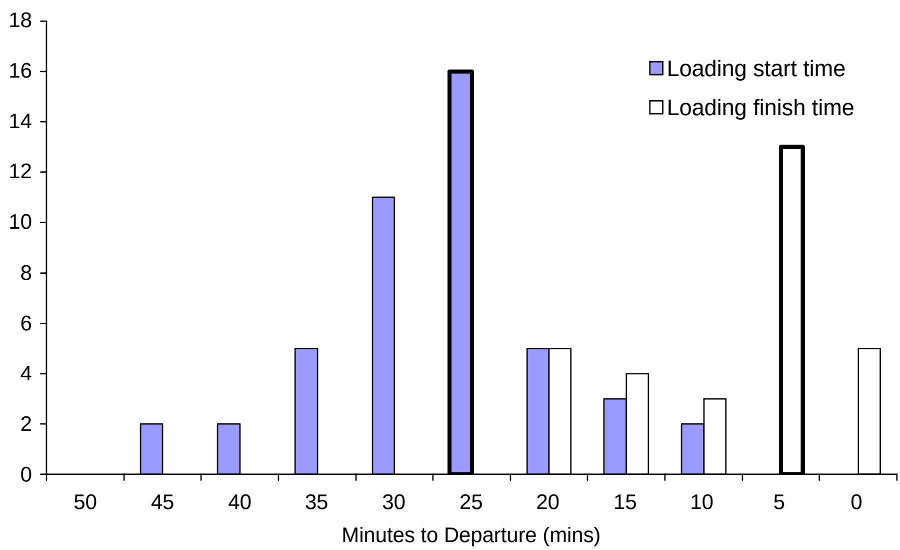

Figure 6. Start and finish times of goods loading

flights, half are delayed due to load connection specifically and the rest are due to late completion of goods loading.

Implications for Airline Operations

Operations control, delay management and ground operation efficiency. The availability of real-time turnaround operating data has significant implications for airline operations control and disruption management. The data captured by the ATMS system clearly shows the start and finish times of each turnaround activity. This real-time information improves the situational awareness of loading supervisors, airport duty managers and operations controllers. The further implication of the data availability is that operations controllers can take proactive measures to reduce departure delays and also mitigate potential delay propagation in the network. The collected time stamps can also be used to evaluate the operational efficiency of different procedures in turning around an aircraft, leading to improvement of turnaround procedures and flight punctuality. Furthermore, the data gathered can be used as service quality indicators, which play an important role in outsourcing contracts of ground handling to third-party handlers. Without detailed operating data for turnaround operations, it would be hard to establish an objective 'service quality indicator' to monitor the operational efficiency of ground handling. Lufthansa has moved towards this direction at its Munich and Frankfurt hubs where Lufthansa does ground handling for other carriers (Mederer & Frank, 2002; Schiewe, 2005; Thon, 2005).

Delay-coding systems. Airlines use delay-coding systems to record delay causes, so delays can be avoided in the future by applying appropriate operational measures. The standard IATA delay-coding system consists of 100 delay codes representing different delay sources (IATA, 2003). Apart from the IATA system, airlines also use in-house delay codes to further detail the causes of delays, hoping that this information will help reduce future delays (e.g. Air New Zealand's delay-coding system improvement by Lee and Moore (2003)). Given the complex involvement of different groups in aircraft turnarounds, it usually takes a few operation coordinators and some radio conversations at a major airport to handle delay code assignment. The disadvantage of this practice, besides human resource costs, is the difficulty to determine the appropriate delay codes, which are truly 'responsible' for delays. This difficulty also prohibits airlines from understanding the underlying roots of delays. To solve this problem, some airlines use more than one delay code for flight delays. Although it seems a good measure for tracing the root causes of delays, this technique actually increases the complexity of delay code assignment and subsequent delay code analyses because the delay-code trees may become too large to analyse.

The developed ATMS system can significantly improve this process because operating time stamps make delay root tracing an easy task for airlines. For instance, delays to passenger boarding finish time can be due to high passenger numbers (causing a long boarding time), late start of boarding, late start/finish of cabin cleaning, late start/finish of catering service, late crewing procedures and/or late connecting passengers. Without clear information of individual turnaround activities, the delay code for this flight could have been assigned as 'passenger boarding delay', which is in fact the consequence of delays instead of the root cause of the delay. This is how collecting turnaround operating data can significantly improve airline operational efficiency as well as reduce delay propagation in an airline network.

Airline schedule planning. Tactical means to control delay propagation in airline networks include schedule changes (schedule disruption management) and operational measures such as speeding up turnaround operations. On the other hand, a strategic means to control delay propagation in airline networks is to 'relax' airline schedules by using buffer times so that unexpected minor delays that emerge from operations can be naturally absorbed. There is less attention paid to developing scheduling algorithms that can provide airlines with optimised allocation of schedule buffer times with the consideration of operational characteristics of individual flights at different airports. Most aircraft routing algorithms available so far are based on the linear programming paradigm, which hardly considers stochastic disruptions from airline operations and flight delay patterns, or only considers aggregate flight delay probabilities (see, for example, Ageeba & Clarke, 2000; Kang, 2004; Lan *et al.*, 2006). Although aircraft routing optimisation can be achieved by linear programming models, the optimised schedule does not guarantee operational reliability, robustness or delay resistance (Mederer & Frank, 2002; Kang, 2004; Wu, 2005). In other words, the global optimum provided by the linear programming models does not necessarily provide the needed reliability and robustness in airline operations against stochastic operational disruptions. The consequence of this scheduling practice is that some parts of an airline schedule may be sensitive to unexpected delays (even minor delays) and minor delays to some flights may cause serious delay propagation in the network. Without detailed data of ground operation characteristics, it is still hard to develop an optimisation algorithm that provides a certain reliability level and schedule integrity against stochastic delays. The application of the developed ATMS system can help collect operating data of airline operations (in particular, detailed turnaround data), and further help in the development of scheduling algorithms of aircraft routing optimisation, which improves the robustness and reliability of airline operations.

Conclusions

Given the significance of aircraft turnaround operations to maintaining the operational integrity of airline schedules, a data collection framework has been proposed to improve the robustness of turnaround operations. A real-time monitoring system which utilises mobile computing devices and wireless network technology has been established based on this proposed framework. Two separate system tests and trials have validated the proposed framework as well as the benefits of using mobile technologies in airline operations control.

Apart from successfully collecting time stamps of turnaround activities, there are some important implications from the perspective of airline operations and schedule planning. First, the availability of real-time operating data makes the turnaround operation a 'transparent' procedure. By automatically monitoring the start and finish times of individual activities, operation controllers can spot potential delay sources, e.g. late loading start, and take proactive measures to minimise departure delays. These proactive measures also play an important role in controlling delay propagation down the lines of aircraft rotations. The saving from reducing reactionary delays, which is roughly 30% of all delay causes, could be tremendous for an airline.

Secondly, the availability of operating time stamps in turnaround can significantly change how airlines record delay codes and how true delay root causes can be identified easily. Given the complex turnaround procedures and resources connection, delay code assignment could be a difficult and time-consuming task because of the difficulty in identifying delay causes and tracing delay roots. With the availability of time stamps of turnaround activities, it is no longer difficult to identify the root cause of delays and delay codes can be easily determined. The further implication is that airlines are able to constantly monitor the operational efficiency of ground handling services and improve the turnaround efficiency in the future.

Thirdly, the availability of operating time stamps can help in the development of airline schedule optimisation algorithms. This advance will not only improve the optimum of aircraft routings but also improve the operational reliability and robustness of airline operations against minor stochastic disruptions. Although the possible benefits to airline schedule optimisation have been identified, some work still needs to be done in the domain of airline schedule optimisation to further prove this proposition.

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