

RESEARCH PAPERS

Modelling and simulation of impact of revenue management on Japan's domestic market

Takeshi Eguchi and Peter P. Belobaba*

Received (in revised form): 16th February, 2004

*Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 33-215, Cambridge, MA 02139, USA

Tel: +1 617 253 7573; Fax: +1 617 452 2996; E-mail: belobaba@mit.edu

Takeshi Eguchi graduated from the MIT International Center for Air Transportation with a Master of Science in Transportation in 2002. His Master's thesis entitled, 'Impacts of Revenue Management on Japan's Domestic Market' provided the basis for this paper. Mr Eguchi is currently at All Nippon Airways in Tokyo, Japan. The focus of his work is on the implementation of RM systems and capabilities.

Peter P. Belobaba is Principal Research Scientist in the International Center for Air Transportation at the Massachusetts Institute of Technology (MIT), and Adjunct Professor of Aviation Management in the International Aviation MBA Program at Concordia University's John Molson School of Business, in Montreal. Dr Belobaba has been involved in research and consulting related to airline revenue management systems at over 30 airlines worldwide. He presently manages the MIT PODS Research Consortium funded by seven international airlines to explore demand forecasting, seat inventory management, network revenue optimisation

and simulation of the competitive impact of revenue management.

ABSTRACT

KEYWORDS: revenue management, simulation, group booking control

Revenue management has been shown to be an effective tool for increasing revenues in a variety of domestic and international airline markets. Owing to the significant volume of group passengers and differences in characteristics between the Japanese and other markets outside Japan, however, it has been difficult for Japanese airlines to determine whether revenue management methods will bring them similar revenue increases if applied to their domestic operations. An investigation of the impact of revenue management on airlines in Japan's domestic market is presented in this paper, taking into account the important role of group bookings in this environment. This paper first introduces the unique characteristics of the Japanese domestic market and describes the business and revenue management processes typically used by Japanese airlines. In preparation for the modelling of group bookings, parameters to describe the behaviour of group bookings are estimated, using data collected from Japanese airlines. Based on

the parameters of the group booking data analysed, a model of the group passenger booking process is then developed and the model's framework is used for simulation.

The Passenger Origin–Destination Simulator (PODS), originally designed to simulate revenue management for individual passenger bookings, is modified to incorporate the group booking process and used for the investigation. Leg-based seat inventory control, specifically fare class yield management (FCYM) with the expected marginal seat revenue (EMSRb) algorithm, is applied as the revenue management method, and it is shown to result in increased revenue for the implementing airline(s) in a representative Japanese domestic market, with group bookings incorporated. The result of simulations of scenarios reflecting the recent integration of two large Japanese domestic carriers and direct competition with a third existing carrier suggest that the revenue gains from using FCYM are as high as 5 per cent when one competitor implements systematic RM forecasting and optimisation. The simulated revenue gains are substantially less under scenarios in which both competitors implement FCYM, at about 1 per cent for each carrier.

INTRODUCTION

Since its deregulation in 2000, Japan's domestic airline market has become gradually more competitive. New airlines started operations with discounted prices, forcing incumbent carriers to lower their fares. Various types of differentiated fares have been introduced by new and established airlines alike, but these fares have not proved to be very effective in terms of airline revenue maximisation. For example, the purchase restrictions applied to discount fares are not strong enough to prevent business passengers (whose willingness to pay is high) from buying such fares. In addition, Japanese airlines have not had great success in implementing systematic revenue management (RM), as they have tended to apply few booking limits to

discount fares, giving too much availability of seats to passengers whose willingness to pay is much higher than the discount fares. The introduction of more effective RM is crucial to Japan's airlines if they wish to maximise revenue, and an evaluation of the expected impact of RM is important to accelerate this introduction.

In order to evaluate the impact of RM on a typical Japanese domestic market, the Passenger Origin–Destination Simulator (PODS), developed at Boeing (Hopperstad, 1997), is used in this study. The impact of RM methods is measured by evaluating the revenues of each simulated airline and analysing the changes in passenger fare mix. Because PODS was designed to simulate demand and bookings by individual passengers, incorporating group passenger demand and the booking process for such passengers into PODS was essential for obtaining results more representative of Japan's domestic air travel markets.

The following section of this paper briefly describes Japan's domestic airline market, and the third section provides some background on the current RM practices used by Japanese airlines, focusing on fare structures and seat inventory control. The fourth section summarises past research related to group RM and the group booking process, and reviews the major sources of variation in group passenger demand. The fifth section provides a brief description of the PODS, and explains how it was modified to handle group passengers' demand and their booking process. The impact of the implementation of fare class RM is simulated in scenarios representative of Japan's domestic market conditions. The final section gives a summary of the findings, and the conclusions of the paper are presented.

JAPAN'S DOMESTIC MARKET

To understand the impact of the introduction of RM on Japan's domestic market, it

Table 1: Domestic market share of largest Japanese airlines

<i>Airline</i>	<i>Passengers (000)</i>	<i>%</i>	<i>RPM* (000)</i>	<i>%</i>
All Nippon Airways (ANA)	39,408	42.4	21,646,061	43.6
Japan Airlines (JAL)	20,215	21.7	12,213,393	24.6
Japan Air System (JAS)	20,322	21.9	10,640,615	21.4

Source: Ministry of Land, Infrastructure and Transportation (2001).

*RPM = revenue passenger miles

is necessary to understand the characteristics of this market first. This section provides a brief overview of the major players in Japan's domestic air travel markets — the airlines, passengers and travel agents. As shown in Table 1, domestic air travel in Japan in 2001 was dominated by three large carriers which accounted for almost 90 per cent of the market. All Nippon Airways (ANA) was the largest domestic competitor, followed by Japan Airlines (JAL) and Japan Air System (JAS).

As is the case in most airline markets, passengers can be classified into three types: individual business passengers, individual leisure passengers and group passengers. The third segment, group passengers, comprises passengers who purchase tickets as part of a travel package. Travel agents typically handle such group requests, so the role of the travel agent is an important factor to consider in the booking behaviour of group passengers.

Much more than in North America and even Europe, travel agents have played an important role in the Japanese industry. Travel agents and airlines cooperate and have joint promotions to induce demand for air travel. Airlines sell tickets to travel agents with special discount prices — group tour (GT) and inclusive tour (IT) fares were used to set lower prices than normal fares even before deregulation, and travel agents could plan low-priced tours or make all-inclusive packages to stimulate demand. In addition, airlines use travel agents to smooth

the demand variation caused by seasonality. Travel agents make contracts with airlines such that they will receive some amount of override commission after they have booked a certain number of passengers. Therefore, travel agents sell tickets even in off-season by lowering ticket prices, as the revenue from the override commission covers the revenue decrease.

Since deregulation in Japan, the market situation has changed, and now airlines are trying to draw more passengers away from travel agents by setting sharply discounted ticket prices on their own, and encouraging passengers to book using the internet. Despite the efforts airlines have made so far, however, it seems that passengers using all-inclusive packages continue to rely on travel agencies, as they like to have everything arranged, including meals and hotels, 'under one roof'.

CURRENT PRICING AND REVENUE MANAGEMENT PRACTICES

Since the completion of the deregulation process, Japanese airlines have gradually begun introducing RM to the Japanese domestic market, using slightly differentiated fare products, as well as seat inventory control based mainly on the experience and knowledge of the staff in the airline's sales department. Since a significant proportion of the Japanese domestic market is group travel, however, identifying current RM practices that target not only individual but also group

passengers is important to simulate the potential impact of more systematic RM. In this section, current fare structures as well as seat inventory control practices for individual and group passengers are reviewed.

Fares structures in Japan's domestic markets

Fares can be classified into two general categories. The first category is referred to as published fares, which appear in the airline's timetable and computer reservations systems (CRS), and individual passengers can buy tickets at those fares. The second category is unpublished fares, which are exclusively used for package tours and cannot be purchased by individual passengers.¹

Table 2 shows a typical published pricing structure used by a Japanese airline. In general, restrictions applied to low-fare products are less strict than in the USA, so that such restrictions are not as effective in preventing high willingness-to-pay passengers from using low-fare products.

The most significant difference between published and unpublished fares is that the unpublished fares are applied to tickets sold as a part of package tours organised by travel agents, so that passengers are unable to separate the price charged for air transportation. Table 3 shows an unpublished fare structure used by a Japanese airline.

— *Individual inclusive tour (IIT) fare*: 30 per cent of passengers using package tours use this fare product. The fare is

Table 2: Published fare products, spring 2001

<i>Fare product</i>	<i>Restrictions on purchase and/or use</i>	<i>Approx. price (% of coach)</i>
Super seat fare	Applied for business class compartment	Coach fare + JPY3,200
Full coach fare	None	100%
Round-trip fare	Round-trip purchase required Trip must be done within 90 days	77–86%
Repeat fares	Multiple tickets for a route purchase required	63–73%
Specified flight discount fare	Applied for specific flights Purchase until a day before departure Non-rescheduling, cancellation/refund penalties Limited seats	47–86%
Advance purchase fare	21–60-day advance purchase required Non-rescheduling, cancellation/refund penalties Limited seats	50–75%
Bargain fare	Applied for all flights in specific period 54–60-day advance purchase required Non-rescheduling Heavy cancellation /refund penalties No seat limitation	JPY10,000 for all flights, which is approx. 21–50%
Other fares	Discount for seniors, child and disabled	45–63%

Table 3: Unpublished fare products, spring 2001

<i>Fare product</i>	<i>Restrictions on purchase and/or use</i>
Individual inclusive tour (IIT) fare	1 minimum night stay at destination required 1–4 passengers required 14–365-day advance reservation required 14–60-day advance purchase required Non-rescheduling, non-transferable, cancellation charge
Inclusive tour (IT) fare	1 minimum night stay at destination required More than 5 passengers required 14–365-day advance reservation required 14–60-day advance purchase required Non-rescheduling, cancellation charge
Group tour (GT) fare	More than 15 passengers required 21–365-day advance reservation required 21–60-day advance purchase required Non-rescheduling, cancellation charge

negotiated between the airline and the travel agent based on parameters such as expected individual passenger demand for the flight and the market share and sales capability of travel agents. The negotiation takes place approximately six months before the package tour goes on the market, and no further negotiation occurs except if actual demand is much lower than forecast.

- *IT fare*: 60 per cent of passengers using a package tour utilise this product. The fare for each package tour is decided through negotiation between the airline and travel agent, and set approximately six months before the travel agent starts selling the product, which is one to six months before departure.
- *GT fare*: Unlike the above products, this fare product is for large groups, such as group passengers going to a large conference, sport teams and so on. Because the schedule for such large groups is more rigid and set well before departure, they tend to book earlier than other group passengers. Conse-

quently, a 21–365-day advance purchase restriction is applied, and the higher fare is imposed. Unlike the above products, only one price is set for these products, and set approximately six months before departure.

Current seat inventory control practices

The RM department of a typical Japanese airline consists of a pricing group and seat inventory control group. The responsibility of the pricing group is to set prices based on the demand forecasts, and change prices as needed. The task for the seat inventory control group is to monitor the booking trend for each route and make any changes to the allocation of capacity to each fare class. Support tools for calculating forecast demand might be available, but RM analysts primarily rely on their knowledge and experience to make their decisions judgementally.

Because there are few connecting passengers in Japan's domestic markets, seat inventory control is leg based, such that the seat inventory allocation for each leg is independent of other legs in their network.

Seat inventory for most flights is divided into two components, inventory for individual passengers buying tickets with published fare products, and inventory for group passengers buying tickets with unpublished fare products. The seat allocation for each inventory is based upon the demand forecast for each type of passenger. As a result, individual passengers whose yield is higher than group passengers may spill in the case where the inventory allocated for individual passengers is already full and there are no unused seats left in the group passenger inventory.

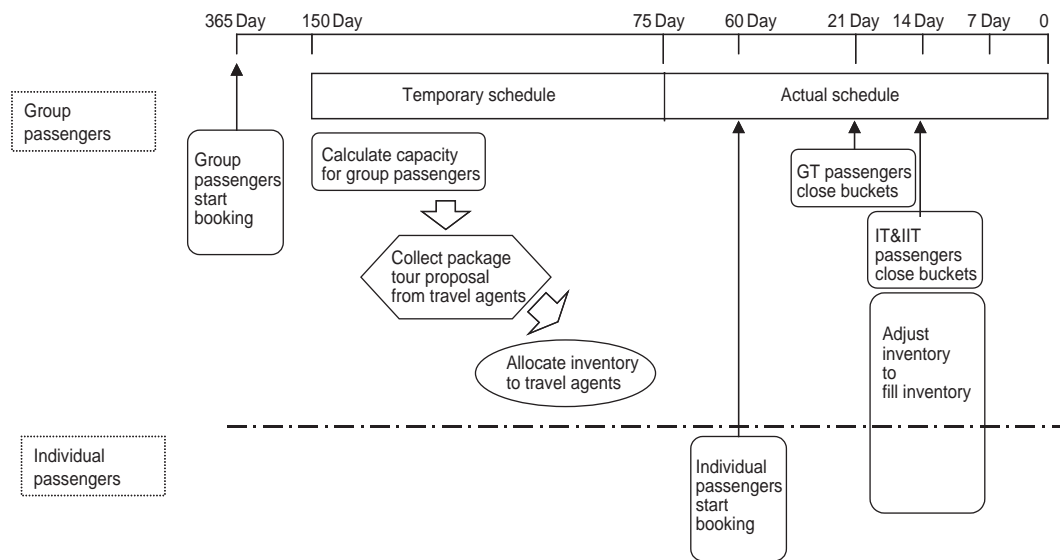
For published fare products, no seat limitation is generally applied to the lowest fare products unless it is a very high-demand flight, so that there is no attempt to increase yield by limiting seats to low-fare products. Also, owing to the fare restrictions, bookings for low-fare products are made earlier than the bookings for high-fare products. Consequently, given sufficient demand for low fares, it is unavoidable that low-yield passengers displace high-yield passengers. For unpublished fare products, this is also the case, and no seat

limitation for low-fare products is set unless passengers using the GT fare, which is the highest among the unpublished fare products, are likely to fill the allocated seats for unpublished fare products.

Overbooking control is also performed manually, based on past no-show data for the same month and same day of the week of the previous year, as well as recent no-show history. In addition, other parameters such as go-show passengers, characteristics of the route and types of passengers are taken into consideration.

Demand forecasting is carried out every half year for all flights. Demand for individual passengers is forecast, and these forecasts are used to decide how many seats should be allocated to individual passengers. The seat allocation for group passengers is then set as the remainder of the capacity. The actual number of boarded passengers is forecast, and the number of no-show passengers forecast is added to calculate the final bookings. Based on the final bookings, a booking curve for each flight is established, and is used to monitor the reservation status. If the actual number

Figure 1: Seat inventory control process



of bookings is over/under the forecast bookings, analysts adjust the number of allocated seats for individual passengers manually.

Figure 1 illustrates this seat inventory control process, which is handled with manual inputs by RM analysts. As a rule, flights that are expected to have a high load factor from individual passenger demand receive little or no seat inventory allocation for group passengers, as it might lead to a displacement of high-yield business passengers. If there is pressure from travel agents to use this flight for group passengers, however, the seat controller within the RM staff can keep group passengers waitlisted and monitor the actual bookings for this flight. If the demand for individual passengers is not as high as expected, the group passengers' booking is confirmed.

The analyst keeps monitoring the reservation status for each flight until the day before departure, and transfers more inventory from individual passengers to group passengers if it becomes obvious that the initial demand forecast is overestimated, and if there is a need to allocate more seats for group passengers. The analysts tend to focus on the load factor of the flight, not the revenue gained from the flight, so they pay little attention to the passenger fare mix.

Flights that are less attractive to business passengers require the RM analyst to provide seats to group passengers to increase load factor. During this period, what the analyst does first is to decide how many seats to protect for individual passengers, based on the demand forecast and past experience. Since low individual passenger demand is forecast for this flight, the remaining seats are allocated to group passengers. Reservations for individual passengers commence 60 days before departure so that the analyst monitors both individual passenger and group passengers booking

status. In this time-frame, airlines ask travel agents to report the number of group passengers booked by 14 days before departure, but they rarely report the actual number of bookings before this cut-off date, in case they expect cancellation from their customers. If the total number of bookings is more than estimated, however, travel agents report the actual number (or more) to obtain more seats for the group.

At 14 days before departure, all travel agents must report the actual number of passengers by sending all names of passengers booked to the airline. Until a day before departure, the analyst works with colleagues to exchange information with regard to the unused seats, and tries to fill the cabin by allocating spilled passengers to other flights. The overall seat inventory control process is highly judgmental and load factor oriented.

MODELLING AND RM OF GROUP BOOKINGS

Past research which considers the group booking/sales process in the context of airline RM is limited. For example, a few presentations have been made at past AGIFORS meetings which focus on dealing with the group booking handling process. Descroix (1989) of Air France presented an expert system for group reservations, to incorporate the knowledge of expert handling of group bookings. Both Lieberman (1990) and Smith (1990) of American Airlines proposed group decision support models, while Bankit (1992) presented an approach for group demand forecasting. Busuttill (1995) of Cathay Pacific described the process to improve the management of the group sales process by improving an airline's internal process, and Kaduwela (1996) of United Airlines presented an overbooking model for group passenger cancellations, dealing with the overbooking for blocks allocated to group passengers.

Apart from these presentations by air-

lines, Svrcek (1991) undertook more extensive research on modelling airline group passenger demand for revenue optimisation. He described the group seat inventory control model using a planning model approach which uses mathematical programming, and a decision-making model which uses displacement cost. Svrcek also identified three major sources of variation associated with group demand — the number of group requests received, the size of each individual group request, and the utilisation rate, a measure of what fraction of the original group passenger bookings will ultimately be used. Each component is described briefly below.

The number of group requests, the first dimension of variability, is the actual number of requests an airline receives for a given flight leg. Note that not all requests are realised, since some are based on travel agent speculation of anticipated demand. The data obtained from a Japanese airline indicate that a significant number of requests remain unused, so that the number of group requests is higher than the number of groups on board. This number of group requests, defined by n , is a discrete random variable, and takes a non-negative integer value. The probability distribution function for n , $p_n(n_0)$, can be expressed as a probability mass function, with impulses of probability with the value of n_0 , a discrete value that n can take.

The size of the group request, the second dimension of variability, is the actual size of each group request received, defined by s . Svrcek noted that the upper bound of s can be on the order of 400 seats, and it may be reasonable to assume that the number of seats travel agents use for an inclusive tour is in multiples of five or ten. In fact, actual data show that a large portion of the data is concentrated on multiples of five or ten. And since s can be treated as a random discrete variable, the probability distribution function for s , p_s

(s_0), can also be expressed as a probability mass function, with impulses of probability, the value of S_0 being a multiple of five or ten.

The utilisation rate is the fraction of seats in the original group request that will ultimately be used by that group (Svrcek, 1991). Thus, the idea of the utilisation rate is the complement of cancellation rate. There is no 'fraction' for each individual passenger, but the utilisation rate can be applied to the aggregate of group passengers, dividing the number of passengers on board by the number of passengers booked. The utilisation rate u can be a continuous number which varies between zero and one. As a result, the probability distribution function for u , $p_u(u_0)$ is again a probability mass function, with the impulses of probability with the value of zero and one, or one may just use average utilisation rate to calculate the final number of group passengers.

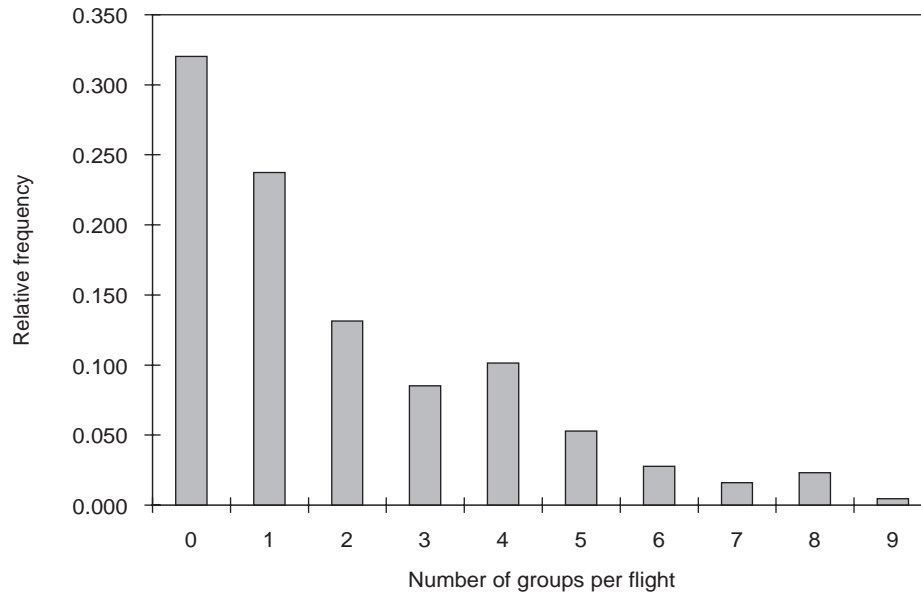
In summary, all three sources of variation take a non-negative, random discrete value, and the probability distribution function of each is a probability mass function. Sample distributions of these group booking parameters, which were obtained from airline data for each group type, are presented in the following sections.

Empirical analysis of group bookings

In this section, group passengers are classified as two types, and analysis of each type is made using sample data obtained from a Japanese airline. Based upon this analysis, group passenger demand is modelled by examining the number of group requests, the size of each individual group request and the utilisation rates associated with a group request.

Group travel is typically categorised into two types, ad hoc and series. Ad hoc is a travel package specially designed for a specific group and trip. Package tours to see festivals, and partake in outdoor activities,

Figure 2: Distribution of number of group requests per flight



such as skiing, are typical examples for this type. In contrast, a series is a type of package which travel agents sell throughout the year to visit popular cities for sightseeing. Actual group booking data for an airline were obtained, which include the type of tour package, day of departure, day of booking, number of bookings involved and actual number of passengers boarded. Utilisation rates for each group were then calculated as the passengers boarded divided by the number of bookings per each tour package. Figure 2 shows the distribution of ad hoc group requests per flight.

Figure 3 shows a histogram of the size of a typical ad hoc group, based on intervals of ten. Analysis of ad hoc group size data showed that that 83 per cent of the data fall within the range $[multiple\ of\ 5 \pm 1]$, suggesting that travel agents typically set the size of such groups using multiples of ten. As a simplification in the simulations, it is assumed that a travel agents use multiples of ten for an ad hoc group.

Figure 4 shows the distribution of utilisation rates for ad hoc groups. As shown in

the figure, more than half the groups in the sample had a utilisation rate of 0, around 20 per cent of the groups had a utilisation rate of 1, and the rest of the groups had various intermediate utilisation rates. The reason for such a bipolar utilisation rate can be explained as follows. Since there is no deposit or cancellation penalty until 14 days before departure, there is no incentive for travel agents to commit groups to specific flights. As a result, travel agents tend to book as many different flights as possible to be able to offer a range of flight options to their group customers. In the end, most of this 'speculative' space is cancelled by the travel agents, resulting in zero utilisation rates on many flights. Conversely, consolidation of passengers into legitimate groups results in a utilisation rate closer to 100 per cent on the flights that are actually chosen for group booking.

Figure 5 shows the distribution of series group requests per flight. Again, readers should keep in mind that not all group requests are actually on board.

Figure 3: Histogram of the size of ad hoc group

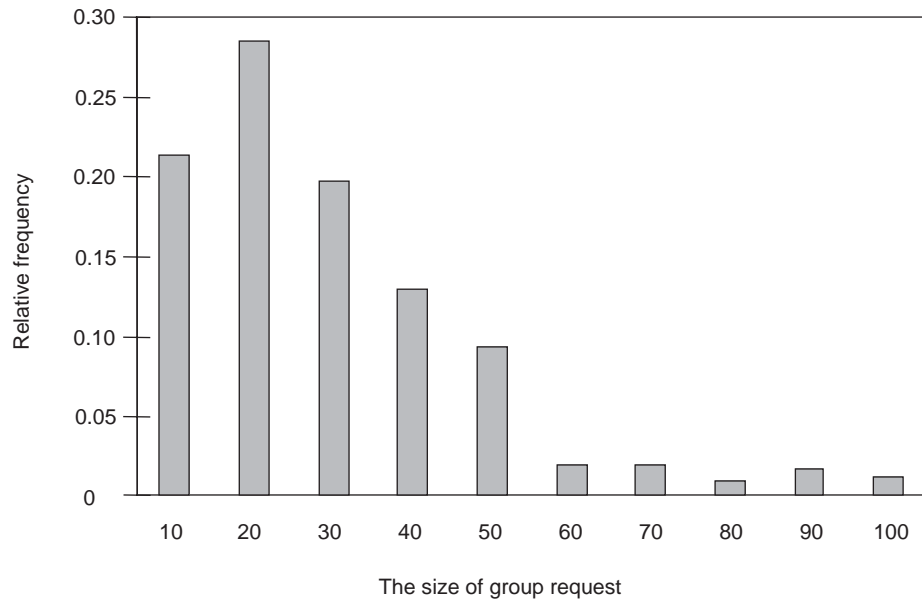


Figure 6 shows a histogram of the size of series group requests, using intervals of width 15. Similarly to ad hoc groups, the observed data show that 85 per cent of the total data lies in [multiple of 15], so that it is plausible to assume that the size of series groups takes multiples of 15.

Figure 7 shows the distribution of utilisation rates for series group requests. The relative frequency at utilisation rate of 0 per cent is close to 0.8, meaning that almost 80 per cent of the groups in the sample had a utilisation rate of 0 per cent. Compared with the ad hoc group requests,

Figure 4: Relative frequency distribution of utilisation rate

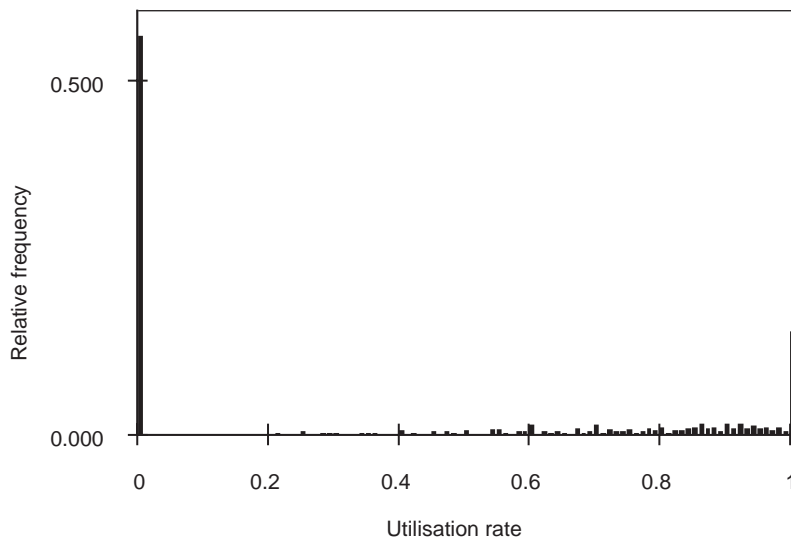
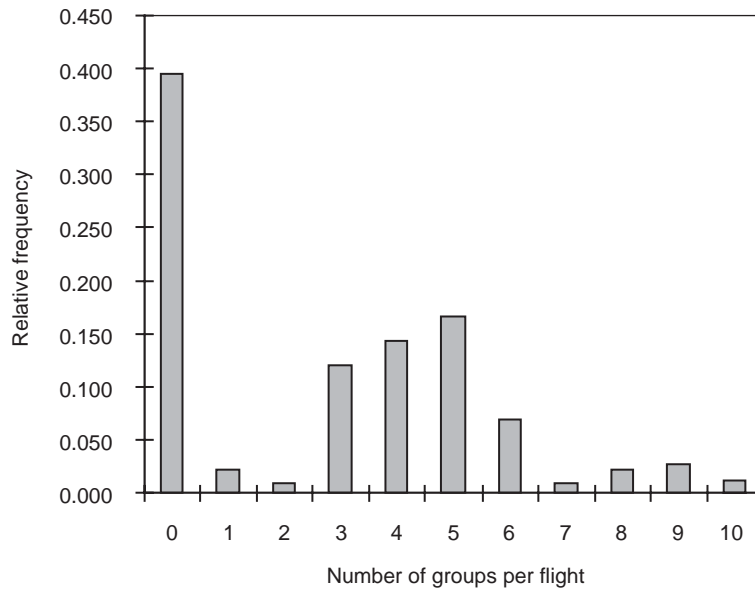


Figure 5: Distribution of number of group requests per flight



the relative frequency with utilisation rate of 0 per cent is significantly higher. This can be explained by the nature of series group requests, in that series type package tours are designed to fit a generic type of passenger. Because of this, it is hard for

travel agents to predict the demand distribution over the days of the week and times of day, resulting in travel agents making more speculative bookings on more flights than they do for an ad hoc package.

Figure 6: Histogram of the size of series group request

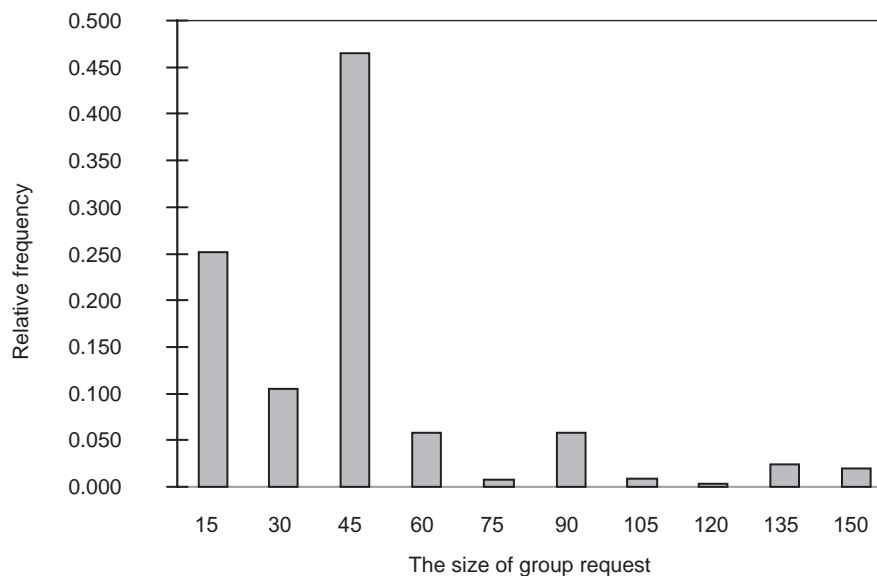
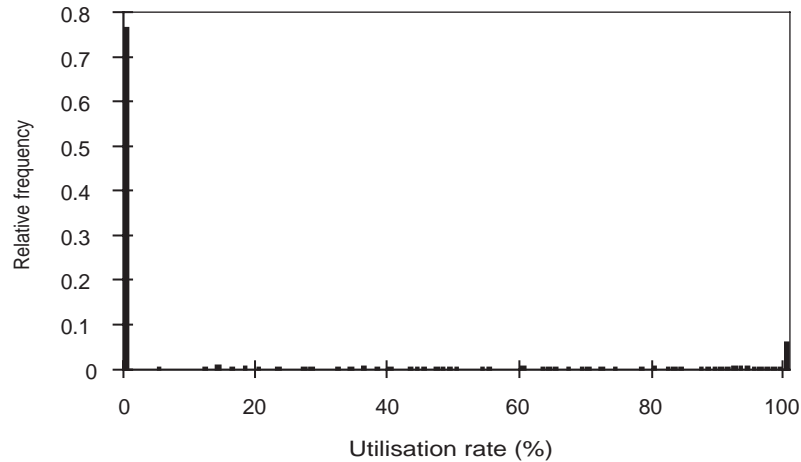


Figure 7: Distribution of utilisation rate for series group request



SIMULATING THE BOOKING PROCESS FOR GROUP PASSENGERS

This section first gives a brief overview of PODS, and then develop a model of the booking process for group passengers to incorporate into PODS. For a detailed explanation as to the basic setup of PODS, refer to Wilson (1995) for a description of the competitive simulation and Skwarek (1997) for its simulated demand forecasting methods. For further information for the RM functions of PODS, readers are directed to recent theses such as Gorin (2000), Lee (2000) and Darot (2001).

Overview of PODS

PODS is a simulator which was originally developed by Boeing, and later enhanced to incorporate yield management simulation capabilities developed at the MIT Flight Transportation Laboratory. PODS uses historical booking data from previous iterations of the simulation for demand forecasts, just as contemporary RM systems do, and enables the simulation of a competitive environment by allowing passengers in the simulation to choose airlines based on both schedules and fares.

Over the past eight years, PODS has

been calibrated to replicate RM system performance and airline outcomes in terms of loads and revenues that are typical of those observed in actual practice by airlines using RM. With the help of its seven member airlines, the PODS Research Consortium at MIT has performed a range of sensitivity analyses to validate the simulation's underlying assumptions, and many of these sensitivity studies have been presented to industry conferences and well documented in the thesis reports referenced above. PODS has come to be regarded by many involved in airline RM research as the 'state of the art' in terms of competitive airline simulations (Belobaba, 2002).

Before a brief explanation of PODS architecture, some of the assumptions used in PODS should be noted. It assumes a stationary process in terms of overall mean demand level. Therefore, PODS simulates many repetitions of effectively the same departure date, without taking into account exogenous factors such as demand growth and seasonal demand change. This simplifying assumption is used in PODS to allow a clearer identification of the impact of RM optimisation and seat inventory control methods, separate from the effects

of alternative demand forecasting methods which would be required under conditions of trend and seasonality. Even under these assumptions, however, the simulation is highly stochastic, generating substantial demand variations and highly variable airline outcomes across the simulated sample of departure dates.

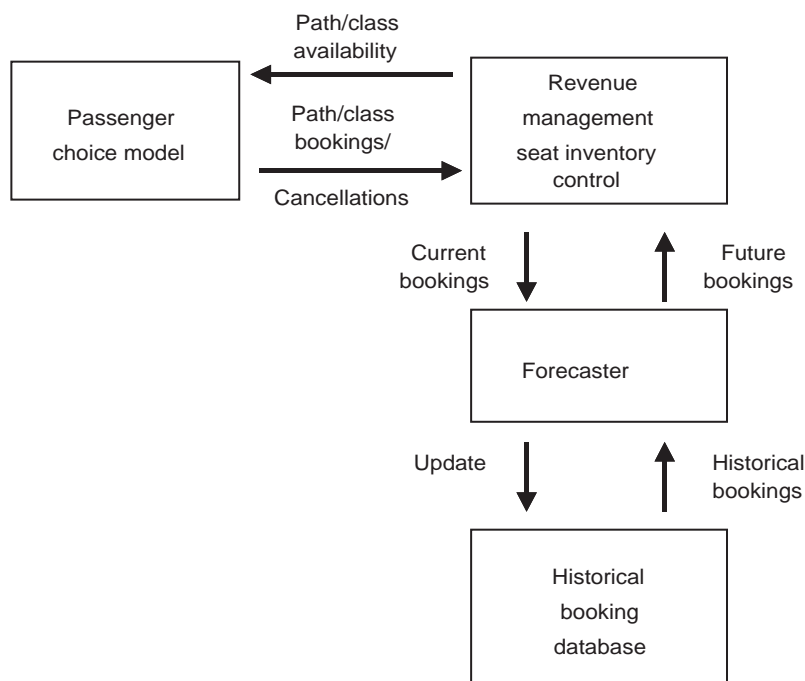
The PODS incorporates two primary processes, passenger choice and RM availability, in its simulation architecture (Wilson, 1995). Figure 8 shows the architecture of PODS. A brief explanation for each module is provided here.

The passenger choice model (PCM) module creates the demand to be used in the simulation, and sends booking requests to the revenue management seat inventory control (RMSIC) module, based the path/fare class seat availability information sent from the RMSIC module. The total mean demand for each market is required as an input parameter, and specified as leisure

and business passenger type demand. Demand by time-frame during the booking period before departure is represented by an input booking curve for each passenger type. For each passenger simulated in the booking process, behavioural attributes such as the passenger's valuation of the perceived costs of any fare restrictions and preferred departure times are generated, and the passenger is assigned to the path/fare class that minimises the passenger's total disutility of travel, given seat availability for the path/fare class as determined by the RMSIC module.²

The RMSIC module determines whether an airline should accept or reject the booking requests that the PCM generates, until there are no more booking requests remaining in the time-frame. Future booking forecasts, used to calculate the RM booking limits for each fare class, are sent from the forecaster module prior to the start of the booking process. After

Figure 8: Architecture of PODS. Courtesy of Hopperstad as reproduced in Zickus (1998: 52)



each booking time-frame, current booking information is sent to the forecaster module to update the bookings for each class.

The forecaster module feeds the forecast demand for each path/fare class to the RMSIC module, based on the historical bookings stored in the database. It also updates the forecast by using the current booking information sent from RMSIC. Finally, the historical bookings database (HBD) module collects and feeds historical booking information to the forecaster module for forecasting future bookings, and updates the database with current booking information.

There are three types of inputs required by PODS. The first type of input is system-level input which defines the fundamental set-up of simulation, such as the number of airlines, number of markets, number of passenger types and so on. The second type of input is airline input parameters, assigned to each airline to specify which methods the airline uses for RM, as well as for the forecasting of expected

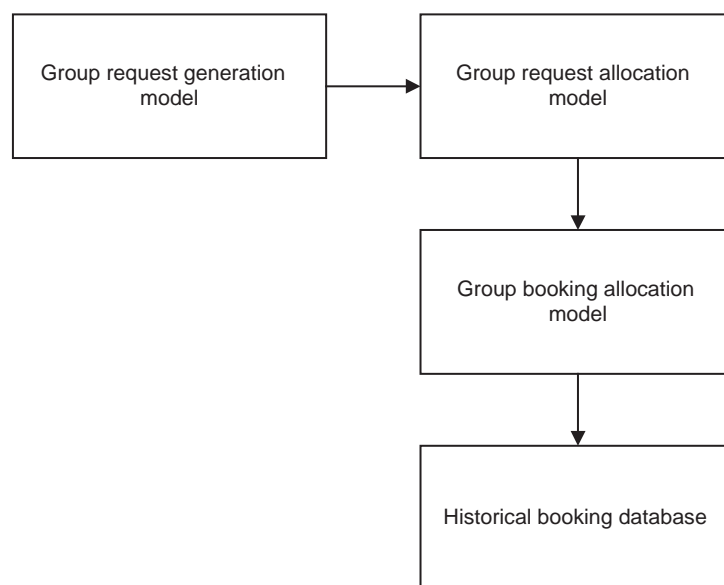
booking demand for each fare class and flight departure. The last type of input is market level parameters, which establishes the characteristics of each market, such as capacity on each leg, distance, time of day and so on. For a detailed explanation, readers are directed to Zickus (1998).

PODS provides detailed simulation outputs in terms of performance measures relevant to airlines. The most important is total simulated airline revenues, averaged over 20 trials, allowing for comparisons of revenue gain under different RM methods. Also useful are measures of passenger leg loads, used to analyse the reason for the increase or decrease in revenue. This output is important, since one can analyse the passenger mix among fare classes, which are affected by the RM methods assigned to each airline.

Booking process for group passengers

Figure 9 displays an overview of the group booking process developed in this paper. The first component, the group request generation model, generates the total

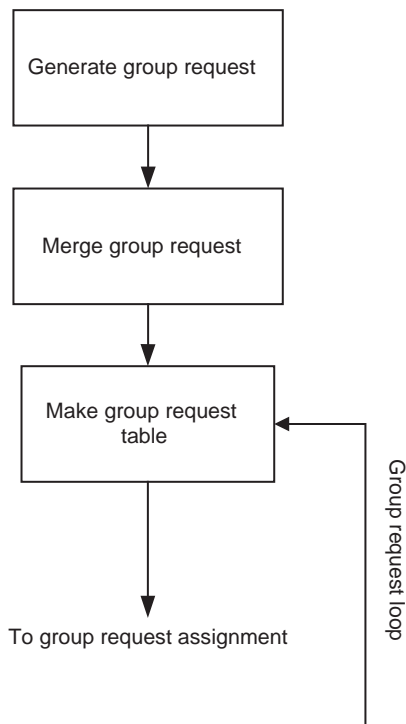
Figure 9: Overview of group booking process



group requests per day. The second component, the group request allocation model, allocates requests to flights by their schedule attributes, and keeps track of group requests for each flight. This inventory is kept until 14 days before departure, when it is handed to the third component. In the group booking allocation model, actual group bookings per flight are calculated using a utilisation rate, and any spilled group bookings are reallocated to flights which still have unused capacity for group bookings. The result of the group booking process for the flights is then stored in the historical booking database, and this result becomes one 'sample'. For each comparison performed, 8,000 samples are simulated, which consist of 20 trials with 600 samples and 200 burns in each trial.

As shown in Figure 10, the first component of Figure 9 is divided into three steps, which are explained as follows.

Figure 10: Request generation flow



Step 1 Generate group request: In this step, the three parameters introduced earlier are used. These parameters are the number of group requests per flight n , the size of the group requests s and the utilisation rate u . First, the number of group requests per flight is generated, and then the size of group is attached to each request. And the last parameter, utilisation rate, is also attached, for use in the group booking allocation model.

Step 2 Merge group request: Group requests for each group type are aggregated to create the total group requests per day.

Step 3 Make group request table: The group requests are then stored to feed the group request to the second component. Table 4 shows an example of aggregated group requests.

Group request allocation

Figure 11 shows the process used to allocate group requests to each flight. The process is much simpler than the same process for individual passengers, since a single fare is applied to each group. Moreover, there is only one leg available so that it is not necessary to choose multiple paths. In this component, the following steps are applied:

Step 1 Determine capacity for group request per flight: The capacity for each flight is calculated to decide how many group requests can be accommodated on each flight. This is calculated as

$$\frac{(Cap - bi)}{u} = \frac{(Cap - bi)}{\sum_k b_k / \sum_k s_k} \quad (1)$$

where Cap is the capacity of each aircraft, bi is the final bookings for

Table 4: Example of aggregated group requests

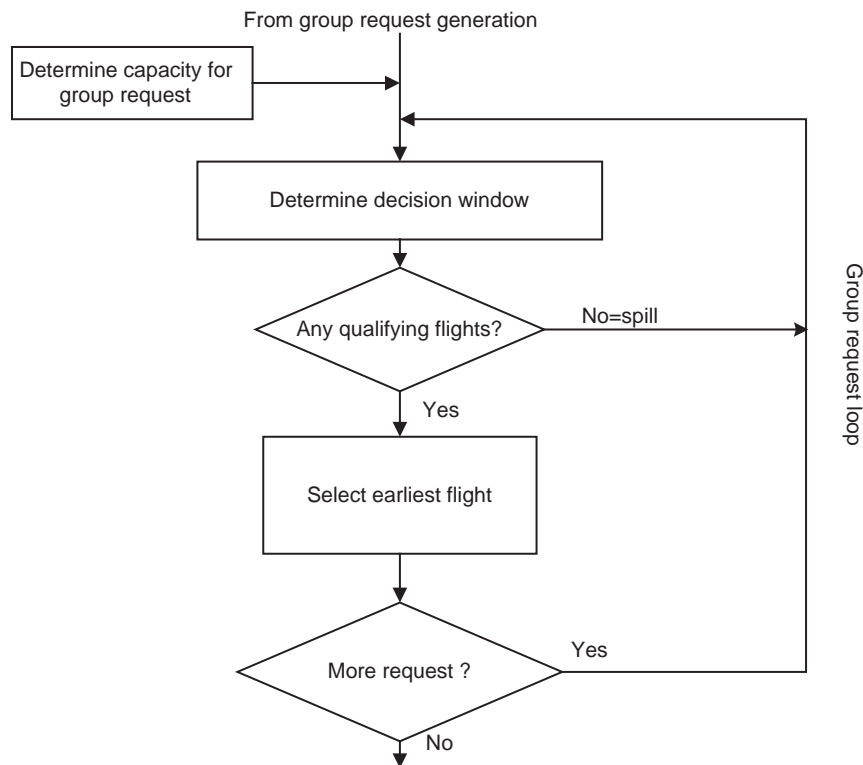
Group ID	Group size	Utilisation rate
1	10	1
2	40	0
–	–	–
50	15	1
51	75	0
–	–	–
100	45	1

individual passengers, obtained from the most recent flights in the historical database, u is the utilisation rate for the flight, b_k is the actual number of bookings for group request k that used the flight, obtained from the most recent flight

in the historical database, and s_k is the size of group request k that booked the flight, obtained from historical database. As described in the previous section, not all passengers in the group request convert into actual passengers onboard. As a result, it is necessary to increase the capacity allocated to group request by multiplying the inverse of utilisation rate for the entire flight, which is calculated in equation (1).

Step 2 Determine decision window for each group request: Similarly to the individual demand in PODS, a time window is assigned to each group request generated in the request generation component explained in the previous section. The position of the time window is defined by the time of day demand curve, and the

Figure 11: Allocate requests to flight



width of time window is based on the schedule tolerance of each passenger type (business versus leisure).³ Because the purpose of group travel is similar to that of individual leisure passengers, the same time of day demand curve was used for group requests. As for schedule tolerance, the value for individual leisure passenger was also used.

Step 3 Allocate group requests to each flight: A group request is picked from the aggregated group requests generated in the previous section and put into the allocating procedure shown in Figure 12. In this procedure, the group request is allocated to the ‘qualified’ flight that both fits the desired time window of the request, and has enough empty capacity to accept such a request. If there are multiple flights available to accommodate the group request, the earliest available flight is used for accommodation. If there is no flight available for the group request, then the request is spilled. This procedure is repeated until there are no more group requests requiring allocation.

Calculate actual bookings and reallocation

At 13 days before departure, all group requests are realised, and all group requests become actual bookings. Based on study of the sample data, and since travel agents need to pay a cancellation fee after 13 days before departure, it is assumed that no cancellation is made after this time, so that all realised bookings become actual passengers onboard. Figure 12 shows the process for calculating actual bookings and reallocation. There are three steps for processing this module, which are as follows:

Step 1 Calculate actual bookings for each group request: Using the utilisation rate

attributed to each group request, actual bookings are calculated as follows

$$s_k \times k = b_k \text{ for all group request } k \quad (2)$$

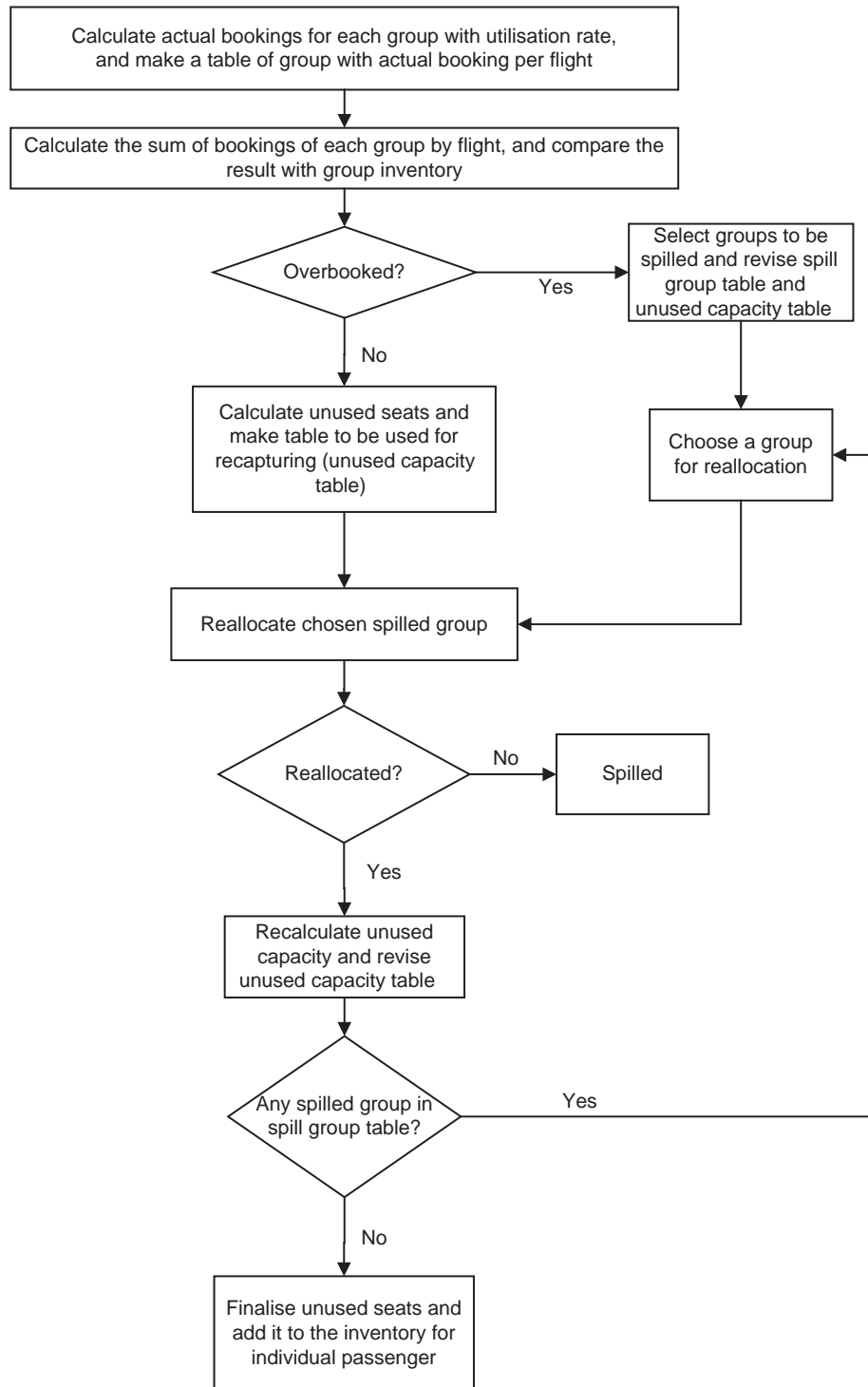
Step 2 Create unused capacity table and spilled group table: The sum of actual bookings per flight is then compared with the actual capacity allocated for group passengers as

$$(Cap - bi) - \sum_k b_k = r_f \quad (3)$$

where Cap is the capacity of flight f , the same as the one used in (1), bi are the final bookings for individual passengers, the same as the one used in (1), b_k are actual bookings per request k in flight f , r_f is the residual of the first and second terms. If r_f is between zero and four, the group inventory for flight f is closed, since this flight cannot accept a group for which the bookings per group is at least five passengers. If r_f is five or greater, the value of r_f is recognised as unused capacity, and it will be used for spilled group bookings. Such unused capacity is stored in the unused capacity table for reallocation process. And, if r_f takes a negative value, this means that the flight is overbooked. As a result, small groups are spilled first, and the size will increment until enough groups are spilled and the sum of remaining actual bookings is less than capacity with the difference smaller than five.⁴ A spill group table is then made to list spilled groups for reallocation.

Step 3 Reallocation: In a reallocation process, large spilled groups are

Figure 12: Booking allocation



given priority to be accommodated first. If there are any flights available, one of the flights with the same airline is selected, and the spilled group is accommodated. If there is no available flight on the same airline, such a group is accommodated by another airline. And if there is no flight available in the market for a spilled group, the spilled group cancels the trip itself, and the group is deducted from the spill group table. The reallocation process continues until no spilled groups remain, and the rest of unused capacity is brought back to the inventory for individual passengers to increase capacity for such passengers.

SIMULATION OF IMPACT OF RM

In this section, the modifications made to PODS to simulate Japan's domestic market are explained first. Then, the simulated revenue impact of introducing systematic RM on the current market are tested using PODS by changing the RM methods of the airlines.

Major modifications to PODS

PODS was modified to incorporate the booking process for group passengers, based on the group booking model described in the previous section. Because it proved difficult to incorporate every feature of the group booking model developed in the previous section, it was decided to modify PODS to include the fundamental concepts of the model. To simplify implementation, for example, an assumption was imposed that the group size follows a normal distribution, with mean equal to ten. Passenger behavioural attributes, such as perceived costs associated with fare restrictions, were set as equal to those of individual leisure passengers.

The group booking process modelled

consists of two steps, group request allocation and group booking allocation, as defined in Figure 9. The first step is to allocate group requests to each flight, and such group requests are realised as group bookings at 14 days before departure. In order to simulate this step, an additional time-frame was first created in PODS, at 70 days before departure. This new time-frame comes at the beginning of the simulated booking process and is used exclusively for group bookings, while individual passengers start their bookings at 63 days before departure, as in the previous version of PODS.

Each group request has an actual utilisation rate of 0 or 1. The previous data analysis of the utilisation rate indicates that 56 per cent of total group requests are cancelled. In order to simulate this behaviour, a cancellation rate, used to simulate the rate of cancellation during each time-frame for individual passengers, is also applied to group passengers as a substitute for utilisation rate. A cancellation rate of 0.6 is set for time-frame 11, which ends 14 days before departure, meaning that 60 per cent of total requests are cancelled before 14 days prior to departure.

There are four fare classes for individual passengers in the baseline PODS scenarios. A fifth fare class was added and used only for group passengers, by closing its booking limit at the first time-frame, 70 days before departure. No fare restrictions are applied to the fifth fare class, as all group passengers make bookings with the fifth fare class.

Market used in simulation

It was announced in November 2001 that Japan Airlines and Japan Air System had reached a basic agreement on integration of the two air transport groups through an incorporated holding company, after obtaining the necessary approvals from the government bodies concerned and the

companies' shareholders (Japan Airlines, 2002). After merger of the two airlines, Japan will have a new 'merged' airline that will possess half the total market share, and drastic change will inevitably follow in Japan's domestic market. In order to analyse the impact of the integration, PODS was run with new settings. Three scenarios — current Airline 1 adopts fare class yield management (FCYM), the new merged Airline 2 adopts FCYM, and all airlines adopt FCYM — were tested.

A single, non-stop route which connects Tokyo and a major Japanese city was selected for simulation. Current market conditions, such as the number of flights per day and the capacity of each leg (flight), were used as input parameters. The relevant data were obtained from published material, such as air traffic statistics collected by the Japanese government, and the timetable of each airline and so on. Owing to confidentiality issues, however, some airline-specific data, such as passenger distributions by fare class, unpublished group fares and so on, were not obtained.

Therefore, the specific data received from one airline were used and applied to others if the same type of the data could not be obtained. Table 5 provides a summary of major market conditions.

Fare structure and demand distribution

Five fare classes (FCLS) were implemented and tested, and four fare classes with three restriction categories were used solely for individual passengers. Table 6 shows the summary of fare classes with restriction categories. The last time-frame for each fare class shows when the fare class is closed. For example, FCLS3 is an advanced purchase fare product, so its last time-frame is 9, which is 28 days before departure. The far right column of Table 6 shows the percentage of total passengers observed in each class.

Table 7 shows the summary of restriction categories applied. Three restrictions are used and, as the value of fare goes down, the number of restrictions applied to the fare class increases. For example, FCLS1 has no restriction, but all restrictions are applied

Table 5: Summary of major market conditions

<i>Parameter</i>	<i>Total</i>	<i>Airline 1</i>	<i>Airline 2</i>
No. of flights per day	35	16	19
Capacity	14,263	6,986	7,277
Airline preference		1.0	1.0

Table 6: Summary of fare classes

<i>Description</i>	<i>Value (\$)</i>	<i>Index</i>	<i>Last time-frame (days before departure)</i>		<i>% of total passengers</i>
FCLS1	469.3	2.26	16	(1)	26
FCLS2	391.9	1.89	16	(1)	26
FCLS3	367.4	1.77	9	(28)	11
FCLS4	207.4	1.00 (base fare)	11	(14)	19
GRP	165.9	0.80	1	(70)	18

Table 7: Summary of restriction categories

<i>Description</i>	<i>Restrictions</i>		
	<i>1</i>	<i>2</i>	<i>3</i>
	<i>High refund charge</i>	<i>Advance purchase</i>	<i>Purchase as a part of travel package</i>
FCLS1	No	No	No
FCLS2	Yes	No	No
FCLS3	Yes	Yes	No
FCLS4	Yes	Yes	Yes
GRP	No	No	No

to FCLS4. As for the group (GRP) fare, only group passengers use this fare, so that there is no need to apply restriction categories for differentiation.

Given some traffic data for this route, an assumption was made that about 50 per cent of total passengers use this route for business purposes, and the rest for leisure trips. Hence, individual business passengers make up almost half the total demand, and individual leisure and group passengers share the rest. Group passengers account for 18 per cent of total traffic, determined from the data on group fare class bookings, with individual leisure passengers making up the rest, 32 per cent.

Simulation results

The first simulation was a 'base case', in which all airlines in the market were assumed to use first come first served (FCFS) as a (non-) RM method. Then, the three cases presented below were run. For the first and second case, Airline 1 or Airline 2 changes its RM method, from FCFS to FCYM, based on forecasting and expected marginal seat revenue (EMSR_b) optimisation. For the third case, both Airline 1 and Airline 2 apply FCYM. Table 8 shows the result of base case and three cases, and Figure 13 illustrates the revenue change for each case, compared with base case.

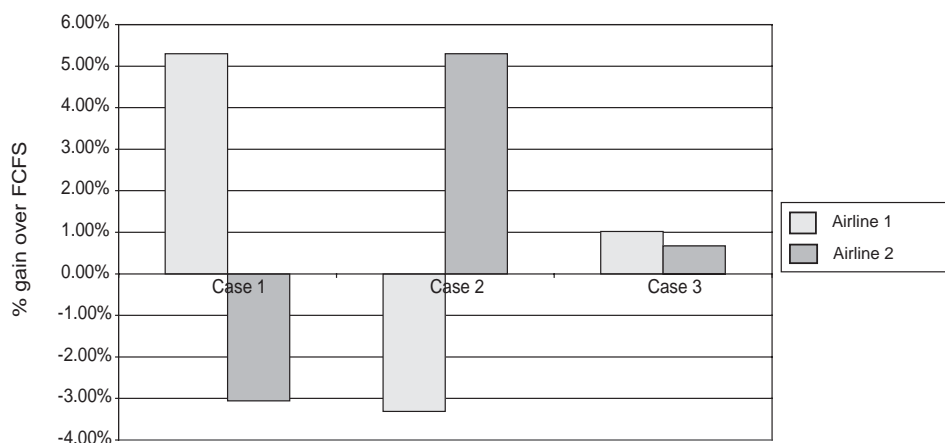
Case 1: Only Airline 1 uses FCYM

As expected, Airline 1 increases revenue by over 5 per cent, a simulated result in line with many previous estimates of the benefits of FCYM over FCFS. In contrast, Airline 2 loses about 3 per cent in revenue when Airline 1 introduces FCYM. The revenue gains and loss come from the way in which the airlines accept bookings. With FCYM, the load factor of Airline 1 decreases in all cases, whereas Airline 2 increases its load factor, accepting more bookings. Despite the decrease in total bookings, however, Airline 1 accepts more bookings in FCLS1 and FCLS2, and reduces the number of bookings in FCLS4 and GRP. Consequently, its yield goes up, resulting in a revenue increase. Airline 2 increases its load factor, but contrary to Airline 1, the number of bookings in higher fare classes is reduced, but increase in lower fare classes, resulting in a yield decrease.

Case 2: Only Airline 2 uses FCYM

As shown in Table 8, Airline 2 gains a significant revenue increase as a result of the implementation of a new method. The pattern of load changes, presented in Table 8, is almost the same as Case 1, and the revenue gain of Airline 2 comes from the yield increase. This is caused by the increase in loads in higher fare classes, and the decrease

Figure 13: Revenue change over base case



in loads in lower classes. As illustrated in Figure 13, Airline 2 gains a revenue increase of over 5 per cent, while the revenue losses amount to about 3 per cent for Airline 1 when it continues to use FCFS.

Case 3: Both Airlines use FCYM

In the last scenario, both airlines implement FCYM. As illustrated in Figure 13, both airlines gain revenue increases, but the gains are smaller when both airlines imple-

ment FCYM. Table 8 shows the load changes in this scenario. In comparison with the yield increase in Scenario 1 and 2, the yield increases in Scenario 3 are smaller. Also, load factors for both airlines go down from 1 to 3 points, counteracting some of the effects of the yield increase.

SUMMARY AND CONCLUSIONS

The objective of this paper was to investigate the impact of RM on Japan's domestic

Table 8: Simulation scenario results

Base				Loads (absolute value)					
Airline	L/F	Revenue	Yield	TTL	FCLS1	FCLS2	FCLS3	FCLS4	GRP
1	78.17	1,817,893	0.5987	5461.21	1423.94	1381.92	613.79	1056.48	985.09
2	76.49	1,861,010	0.6013	5566.33	1473.06	1424.97	617.95	1061.44	988.91
<i>Case 1: Only Airline 1 uses FCYM</i>				<i>Loads change (compared with base case) (%)</i>					
1	76.96	1,914,309	0.6404	-1.56	24.35	3.29	1.29	-14.93	-33.24
2	77.01	1,804,026	0.5790	0.68	-6.65	-4.02	-15.63	-2.57	32.03
<i>Case 2: Only Airline 2 uses FCYM</i>				<i>Loads change (compared with base case) (%)</i>					
1	78.31	1,757,666	0.5779	0.17	-6.06	-3.48	-17.52	-6.94	32.94
2	75.51	1,959,668	0.6414	-1.28	22.26	3.72	3.75	-12.86	-34.28
<i>Case 3: Both Airlines use FCYM</i>				<i>Loads change (compared with base case) (%)</i>					
1	75.26	1,836,490	0.6283	-3.73	10.33	5.54	-3.07	-13.11	-27.42
2	73.73	1,873,505	0.6280	-3.61	8.49	4.36	-1.32	-10.17	-27.52

market, where group passengers cannot be neglected. In order to understand the characteristics of the market, a brief overview of the Japanese domestic market was presented, highlighting the importance of group traffic and the role of travel agents. The current approach to pricing and RM used by a typical Japanese carrier was then described. The existing seat inventory control practice is effectively a First FCFS, leg-based control, which depends on manual intervention and analyst judgment. Given this very basic level of RM practice, the move towards more systematic RM methods would be expected to increase revenues for Japanese airlines. The added complexity of group booking control and uncertainty about the actual revenue gains that might be realised, however, has prevented Japanese airlines from embracing more automated RM methods.

Based on review of previous works related to modelling and managing the group booking process, an empirical analysis of group passenger data obtained from a Japanese airline was performed. Group passengers were classified into two types, ad hoc and series, and the most important parameters of group bookings — the number of groups per flight, the size of groups and their utilisation rates — were analysed based on the sample data. The results of this empirical data analysis and previous works on the modelling of airline group bookings were then applied to the development of a group booking process model. This model of the airline group booking process developed in this paper provides new insights as to the differences between individual and group bookings, as well as a framework for the simulation of group bookings.

The application of this model to the simulation of the impact of RM in an environment in which group bookings represent a significant proportion of total traffic was then demonstrated by incorporating the major components of the model

into PODS. The simulation capabilities of PODS, previously limited to individual passenger bookings, were modified to simulate the mix of individual and group passenger bookings typical of Japan's domestic market. The modified version of PODS was then used to simulate an airline market between Tokyo and a major Japanese city, with the goal of estimating the revenue impact and changes in fare class mix that more systematic RM could bring to the airlines competing in such markets.

The simulation results showed that an airline implementing even a basic leg-based FCYM method which accounts for the presence of both individual and group demand in an integrated fashion would experience a substantial revenue gain. When either one of the two simulated competing carriers implemented FCYM, the implementing airline showed revenue gains of about 5 per cent over an FCFS approach. In line with previous PODS results, the implementation of this RM method by either airline also results in a revenue loss of about 3 per cent to the other airlines that do not implement systematic RM. At the same time, when both major competitors implement FCYM, the revenue gains are still positive for both carriers, but are substantially lower at around 1 per cent for both.

The implications of these simulation results should be clear, not only for airlines in the Japanese market, but also for airlines operating in markets with significant group passenger demand. The apparent complexity and constraints imposed on the management of seat inventory in a mixed individual and group booking environment should not be used to rationalise continued delays in the implementation of more systematic approaches to RM. Even the most fundamental leg-based fare class forecasting and optimisation tools used by most airline RM systems will provide a substantial improvement in the handling of seat inventories over the manual methods used by

many airlines in similar situations. More importantly, gaining a competitive advantage by implementing an RM system in such an environment can lead to substantial increases in passenger revenues. The group booking process model and its use in a simulation of RM impact, as presented in this paper, represents an important step in quantifying the benefits of RM methods in a more complex, and more realistic, simulation environment.

NOTES

1. It is prohibited by contract between travel agents and airlines for agents to sell tickets to their customers at unpublished fares, but some agents are in breach of contract and sell tickets as Air-Only tickets.
2. For a detailed explanation about attributes, readers are directed to Lee (2000).
3. For further details on decision window and schedule tolerance, refer to Wilson (1995: 51–52).
4. It is intuitively understandable, since a large size group is hard to accommodate again, and it might be spilled to other airlines.

REFERENCES

- Bankit, P. (1992) 'Group demand forecasting', presentation to AGIFORS Reservations and Yield Management Study Group, Brussels, Belgium, Proceedings, 172–185.
- Belobaba, P. P. (2002) 'O-D Control: What have we learned?', presentation to PROS 9th Annual Pricing and Revenue Optimization Conference, Houston, TX, 25th September.
- Busuttill, L. (1995) 'Managing the group sales process', *35th AGIFORS Symposium Proceedings*, AGIFORS Communications Office, Memphis, TN, 153–160.
- Darot, J. F. (2001) *Revenue Management for Airline Alliances: Passenger Origin-Destination Simulation Analysis*, International Center for Air Transportation, Massachusetts Institute of Technology, Cambridge, MA.
- Descroix, D. (1998) 'An expert system for groups reservations', *29th AGIFORS Symposium Proceedings*, AGIFORS Communications Office, Memphis, TN, 79–96.
- Gorin, T. O. (2000) *Airline Revenue Management: Sell-up and Forecasting Algorithms*, International Center for Air Transportation, Massachusetts Institute of Technology, Cambridge, MA.
- Hopperstad, C. A. (1997) 'PODS: Modeling update', presented at the AGIFORS Yield Management Study Group, Montreal, Canada.
- Japan Airlines (2002) 'JAL/JAS integration approved by Japan's Fair Trade Commission', *News Release*, 26th April: <http://www.news.jal.co.jp/EJAL_NEW.ns4>
- Kaduwela, V. P. (1996) 'A stochastic overbooking model to account for retail/group passenger cancellations', *36th AGIFORS Symposium Proceedings*, AGIFORS Communications Office, Memphis, TN, 105–118.
- Lee, S. (2000) *Modeling Passenger Disutilities in Airline Revenue Management Simulation*, International Center for Air Transportation, Massachusetts Institute of Technology, Cambridge, MA.
- Lieberman, W. (1990). 'A group reservations decision support system', presentation to AGIFORS Yield Management Study Group', Rome, Italy, *Conference Proceedings*, 69–82.
- Ministry of Land, Infrastructure and Transportation (2001). *Monthly Aviation Statistics*, August, Tokyo, Japan.
- Skwarek, D. K. (1997) *Competitive Impacts of Yield Management System Components: Forecasting and Sell-Up Models*, International Center for Air Transportation, Report R97-X, Massachusetts Institute of Technology, Cambridge, MA.
- Smith, B. (1990) 'A group decision support model', *30th AGIFORS Symposium Proceedings*, AGIFORS Communications Office, Memphis, TN.
- Svrcek, T. (1991) *Modeling Airline Group Passenger Demand for Revenue Optimization*, Flight Transportation Laboratory, Massachusetts Institute of Technology, Cambridge, MA.
- Wilson, J. L. (1995) *The Value of Revenue Management Innovation in a Competitive Airline Industry*, International Center for Air Transportation, Massachusetts Institute of Technology, Cambridge, MA.
- Zickus, J. S. (1998) *Forecasting for Airline Network Revenue Management: Revenue and Competitive Impacts*, International Center for Air Transportation, Massachusetts Institute of Technology, Cambridge, MA.