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Applied Two-Class Overbooking Model in Thailand's Passenger Airline Data

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ABSTRACT

In this study, a mathematical model, which combines two of the most important airline revenue management strategies, namely overbooking and seat inventory control, is applied in Thailand's passenger airline data. Using this model, it is possible to find a closed-form solution for both the optimal booking limit and the optimal overbooking limit, simultaneously. Numerical study was set to evaluate the performance of the two-class overbooking model and to test three hypotheses using real-life data. Our two-class overbooking model outperformed the fixed-booking limit policy. Moreover, three hypotheses: the effect of varying the number of update booking limit points, the effect of an incorrect initial mean for demand, and the effect of a number of smoothing constants on an exponential smoothing method were tested using real-life data. At the 0.05 significance level, it was found that different numbers of update booking limit points affected profit, incorrect initial mean for demand did not affect profit when a high number of update booking limit points was set, and all of the smoothing constants in exponential smoothing method affected profit to some extent.

1. Introduction

Airline industry, with high fixed costs and low marginal costs, is a prime candidate for using revenue management (RM) to improve profitability. According to the Air Transport Information Division of AOT (AOT, Airport of Thailand Public Company Limited), total air traffic in Thailand increased by 21 percent from 2014 to 2015, aircraft movement increased by 17 percent, and passenger numbers by 21 percent. In value terms, this generated an increase of about $167 million U.S. of revenue to the country. "Thailand is set to grow and benefit from the rising demand in global aviation thanks to its available skilled human resources, geographical advantage, and strong government support (Boric, (2016))." The airline company in Thailand could benefit from using RM.

The capacity allocation problem when the airline has multiple fare classes can be formulated as as Markov decision processes, see e.g. Brumelle and McGill (1989), Subramanian et al. (1999), Gosavi et al. (2002), Lan et al. (2011), and Aydin et al. (2012). Most do not possess the closed-form solutions except Aydin et al. (2012). Aydin et al. (2012) assume that the random vector of booking request follows a multinomial distribution. The two-class model is a basic building block for the multi-

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class model. Two-class overbooking model proposed by Somboon and Amaruchkul (2016) assumes general distribution for the booking request. This model that combined overbooking and seat inventory control is applied to a passenger airline.

Overbooking and seat inventory control have the same objective in terms of maximizing the expected profit. Overbooking increases revenue by accepting the number of reservations greater than capacity to compensate for cancellation and no-shows. The two-class overbooking model contains two customer classes, class-2 (low fare) customers and class-1 (high fare) customers, and assumes that class-2 customers arrive before class-1 customers. This model includes a penalty cost that the airline incurs when rejected booking request. The show-up rates of two classes may be different and the airline may overbooking class-2 customers. An optimal overbooking limit that maximizes the total expected profit is derived.

The famous Littlewood's rule for two classes that focuses on the booking control problem was proposed by Littlewood in 1972. This problem assumes two product classes with associate price that arrives sequentially and assumes no cancellation or no-shows (hence, no overbooking). In 1975, Shlifer and Vardi study two-class overbooking model but does not include the booking control problem. Overbooking and booking control problem combined in two-class model in Sawaki (1989) and Ringbom and Shy (2002). Littlewood's rule was extended to allow no-show passengers in Sawaki (1989) and Ringbom and Shy (2002). The assumption of the booking requests of the two classes are assume to be continuous in Sawaki (1989) and bivariate normal in Ringbom and Shy (2002) while the booking request can be any non-negative integer random variable in Somboon and Amaruchkul (2016). The refund in Ringbom and Shy (2002) is fully given to class-1 and class-2 received no refund, whereas in Somboon and Amaruchkul (2016), the refund needs not be fully given but the refunds can be given to both classes. The booking request is accepted up to the overbooking limit and additional requests are rejected similar to other overbooking model. The penalty (loss-of-goodwill) cost that the airline incurs when rejected the booking request is given to each rejected booking request in Somboon and Amaruchkul (2016) but only class-1 rejected booking request in Sawaki (1989). In practice, refund and penalty scheme from Somboon and Amaruchkul (2016) are more general and fit.

Generally, one of tactics that increasing success in RM is accurately forecasting demand. The reservation system accepts the booking requests up to a pre-determined booking limit. Hence, demand in that fare class for a given flight may exceed the booking limit, but historical data shows only the number of reservations. At the booking limit, the demand is called censored demand in the field of statistics or constrained demand for a passenger airline. The method to uncensor data is called unconstraining. In 2002, Weatherford and Pölt reviewed unconstraining methods; the simplest three are as follows: 1) Naïve 1 (N1) replace all constrained observations with the mean of all observations, 2) Naïve 2 (N2) replace all constrained observation with the mean of all unconstrained observations, and 3) Naïve 3 (N3) replace constrained observation less than the mean of all observations with the mean of all unconstrained observations. These methods are used to forecast demand before using the two-class overbooking model.

The rest of the paper is organized as follow. The model is formulated and analyzed in Section 2. Section 3 describes the detail of real-life data and testing hypothesis. Section 4 concludes our paper.

2. Two-Class Overbooking Model

In practice, an optimal booking limit is re–solved periodically to account for change in show-up probability and proportion of refund cost over time, resulting in overbooking limits that vary over time. In this model, let t be the number of days before departure and let $\mathbb{R}$ and $\mathbb{Z}_+$ be a set of real number and the set of non-negative integers respectively and let $(y)^+ = \max(0, y)$, for $y \in \mathbb{R}$. The quantile function of the distribution function of random variable $D(t)$ is denoted as

$$F_{D(t)}^{-1}(a) = \inf\{x : P(D(t) \le x) \ge a\} .$$

An airline with two customer classes that have fixed capacity κ is considered. In this model, class-2 reservations are assumed to start reservation before class-1. The airline earns revenue p_i when a class-i customer is accepted, $p_1 > p_2 > 0$, for each $i =$ 1, 2. If the airline rejects the booking request, the airline incurs a penalty cost g_i where $g_1 > g_2 > 0$. The penalty cost in this model includes the loss-of-goodwill cost and the opportunity cost. The loss-of-goodwill measures customer satisfaction that may be intangible and can be difficult to estimate in practice. The opportunity cost measures future revenue loss that depends on what happen after the lost sales occur. The opportunity cost is the expected revenue loss from this event if a customer is likely to return to make a booking request. The opportunity cost includes all future revenues if a customer never returns to make any booking with the airline.

Let $x(t) \in \mathbb{R}_+$ be a booking limit of class-2 at the update booking limit point t days before departure, i.e. class-2 reservations are accepted up to $x(t)$. Allowed overbooking, $x(t)$ can be greater than capacity $\kappa(t)$ where $\kappa(t)$ is capacity at the update booking limit point t. For each $i =$ 1, 2, let $D_i(t)$ be class-i demand at the update booking limit point t, the number of class-i booking requests. $D_1(t)$ and $D_2(t)$ are assumed to be two independent non-negative discrete random variables. At the update booking limit point t, the number of class-2 reservation is $\min(x(t), D_2(t))$, and the number of class-2 rejected is $(D_2(t) - x(t))^+$.

After class-2 reservations all arrive, class-1 customers start their booking. The remaining capacity after class-2 arrives is $(\kappa(t) - \min(x(t), D_2(t)))^+$. We do not overbook class-1 because class-1 passengers are of high priority or extremely high penalty cost. Class-1 customers are accepted up to the remaining capacity. For $i = 1, 2$, let $B_i(x(t))$ be the number of class-i reservations at the update booking limit point:

$$B_2(x(t)) = \min(x(t), D_2(t)) , \quad B_1(x(t)) = \min((\kappa(t) - B_2(x(t)))^+, D_1(t)) .$$

Before departure time, some reservation may cancel prior to or do not show up. In this model, cancellation and no-show passengers are the same. Given that the number of class-i reservations is $B_i(x(t)) = y_i$, the number of class-i show-ups, denoted by $W_i(y_i)$, is assumed to follow a binomial distribution with parameters y_i and θ_i where $\theta_i \in (0,1]$ is the show-up probability of class-i. That the binomial distribution is an adequate model for the show-ups distribution has been showed in Tasman Empire Airways (Thompson, 1961). Each class-i reservation that does not show up receives a refund r_i, which is a proportion γ_i of revenue cost where $\gamma_i \in (0,1)$; $r_i = \gamma_i p_i$ for $i =$ 1, 2.

At the departure time, if the number of show-up passengers over capacity, some passengers are denied. Recall that we overbook only class-2 passenger, so all denied boarding passengers are class-2. A compensation h must pay to all passenger who denied boarding where $h > p_2$. This compensation may include a fare of a higher booking class on a next flight, vouchers for cash or tickets for future travel, and/or hotel accommodation.