Journal of Air Transport Management 53 (2016) 65–72

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Customer perspective on overbooking: The failure of customers to enjoy their reserved services, accidental or intended?

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ARTICLE INFO

Article history:
Received 21 October 2015
Received in revised form
5 January 2016
Accepted 5 January 2016
Available online xxx

Keywords:
Compensation
Denied service
Overbooking
Reservation
Service provider

ABSTRACT

Overbooking is widely applied in the service industry to hedge against undesirable situations, such as cancellations and no-shows. However, during the implementation of overbooking, service providers may turn down some customers when the number of arrivals exceeds their capacity on the target date. Therefore, this paper examines overbooking from the customers' perspective to offer them a clear perception on the possibility for their reservations to be denied by the service provider. By establishing a Stackelberg model between a service provider and an online travel agency, we explore how optimal overbooking strategy is developed by the service provider. Afterward, by analyzing the obtained optimal overbooking pad, we calculate the probabilities of denied service under different levels of monetary compensation that is paid to denied customers. A higher monetary compensation guarantees a higher chance of successful service. This paper also provides customers with some reference when booking services.

1. Introduction

One of the distinct features of the service industry is the perishability of its products/services (e.g., airline tickets and hotel rooms). Perishable products differ from tangible commodities on five aspects (Rücker, 2012), among which the most typical two are as follows. (i) Perishable products generally have high fixed costs and low variable costs, which considerably boosts the marginal profit per product (Ladany, 1996; Guo et al., 2013b). (ii) Unsold service products have a zero residual value and cannot be kept in inventory for future use (Stolarz, 1994). Consequently, when services are not fully consumed in a certain period, service providers face large revenue losses.

Service providers have adopted various marketing/operations strategies, such as dynamic pricing (Jallat and Ancarani, 2008; Palmer and McMahon-Beattie, 2008), market segmentation (Füller and Matzler, 2008; Guo et al., 2013b) and overbooking (Schütz and Kolisch, 2013; Toh, 1985), to fully utilize their finite capacity or to maximize their occupancy rate. Among these strategies, overbooking, in which reservations are offered in excess of product capacity, is widely applied to hedge against the capacity idleness that is caused by cancelations and no-shows (C&NS), which are commonplace in service industries (Amaruchkul and Sae-Lim, 2011; Chatwin, 1999; Klophaus and Pölt, 2007; Mauri, 2007).

Although overbooking helps service providers increase the utilization of their finite capacity, this strategy can also be a double-edged sword because some customers are denied of service when the number of arrivals exceeds the capacity. Such denial is a terrible experience for customers (Zhang et al., 2010; Lindenmeier and Tscheulin, 2008; Hannigan, 1980). Service providers also incur disrepute and economic losses when they have no choice but to refuse customers. For instance, on June 24, 2011, a group of 13 passengers who had ordered tickets in advance through China Southern Airlines was informed that only three tickets were left upon their arrival at the airport because of overbooking (http://www.chinanews.com/cj/2011/06-26/3137099.shtml). The passengers felt that the airline infringed their agreement, which prompted the company to arrange another flight for these passengers without any charge, return 50% of their ticket fare, and provide these passengers with accommodation and follow-up service as they waited for their next flight.

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http://dx.doi.org/10.1016/j.jairtraman.2016.01.001
0969-6997/

Although denied customers may obtain compensation from service providers, such compensation is mostly negligible compared with the serious consequences of schedule disruption. For example, businessmen who miss a flight will have their work plans disrupted or miss important meetings, which can induce immeasurable losses.

Consequently, a terrible overbooking decision will not only hurt the reputation and revenue of service providers, but also cause immeasurable losses for the customers. Therefore, service providers must develop a proper overbooking strategy to increase their profits, while customers must understand such strategy to avoid being denied of service.

This paper analyzes the optimal overbooking strategy of a service provider (an airline or a hotel) by modeling a Stackelberg game with an online travel agency (OTA) in the e-business environment. From the customer perspective, the possibility for a denied service is then analyzed based on the identified optimal overbooking strategy.

The optimal overbooking pad of the service provider decreases along with the monetary compensation that they pay to their denied customers. Therefore, a higher monetary compensation ensures a lower probability of denied service when customers request for reservations. Customers can estimate the possibility of a denied service according to the announced non-performance penalties of service providers and then select the most desirable service providers in case of schedule disruptions. In turn, service providers must announce the value of their compensation to their customers to reassure them that they will not be denied of any service.

The rest of the paper is organized into several sections. After reviewing the related literature in Section 2, Section 3 describes the developed model between a service provider and an OTA and then analyzes the methodology for solving the optimal overbooking strategy of the service provider. Section 4, discusses the probability for those customers with reservations to be denied of service. Section 5, illustrates the solutions for the optimal overbooking pad by presenting a numerical example, and then identifies the probabilities of denied service under different values of monetary compensation. Finally, Section 6 concludes the paper by summarizing the findings, implications, and directions for future research.

2. Literature review

Many publications have examined how service providers set appropriate overbooking levels and apply such strategy in managing their revenues. Weatherford and Bodily (1992) examine the interrelatedness among overbooking, pricing, and yield management, which is also called perishable-asset revenue management in the service industry. To explore the effect of customer C&NS on yield and pricing policy, Badinelli (2000) suggests that the cancellation and “walking” processes of customer reservations must be examined along with the arrival process. Overbooking is an effective non-pricing tool for revenue management (Hadjinicola and Panayi, 1997; Ivanov and Zhechev, 2012; Lan et al., 2007). Rothstein (1971) introduces a model for determining the airline overbooking policy and obtaining its optimal solutions. By comparing the inventory level of a previously confirmed reservation with the number of unconfirmed new requests, the hotel adjusts its overbooking level to maximize its net profit (Liberman and Yechiali, 1978). Similarly, by adopting a booking-limit policy to handle the airline overbooking problem, Chatwin (1999) suggests that the airline must decide whether to accept new reservation requests or not by checking the number of initial reservations. Rothstein (1974) introduces a decision model for hotel booking policies and specifies the overbooking practice by controlling the risks and costs of oversales.

The application of the overbooking strategy in highly complex conditions has also been examined. Koide and Ishii (2005) analyze hotel overbooking problem with two types of room prices, assuming that customers book a room with early discount. Karaesmen and Van Ryzin (2004) consider an overbooking problem with multiple reservation and inventory classes in which customers can be assigned to various inventory classes to maximize the net benefit of assignments. Ivanov (2015) studies the hotel overbooking limits and assumes that the reserved rooms can be upgraded or downgraded by one level. In one of his earlier papers, Ivanov identifies the optimal overbooking limits for guaranteed and non-guaranteed hotel reservations (Ivanov, 2007). Other articles have also analyzed the application of the overbooking strategy in the hotel and airline industries (Aydin et al., 2012; Chatwin, 1996; Coughlan et al., 1999; GOSAVII et al., 2002; Lan et al., 2011; Liberman and Yechiali, 1978; Subramanian et al., 1999; Toh, 1975).

In most of the aforementioned overbooking models, the show demand is assumed to be a linear product of the overbooking level and show-up rate. Amaruchkul and Sae-Lim (2011) suggest that this assumption may be deficient under certain conditions. Therefore, they explore such model misspecification.

Instead of developing a model to set an optimal overbooking level for service providers, other researchers have examined the behavior of customer no-shows. Garrow and Koppelman (2004) study the no-show and standby behavior of airline travelers using passenger and directional itinerary data, which can help carriers develop highly accurate forecasting models. Dupuis et al. (2012) examine a logical approach for analyzing the data for estimating passenger show rates at Air Canada and reveal that such approach can offer accurate predictions.

However, when the number of arriving customers exceeds the capacity, overbooking may result in oversales and denials (Baker et al., 2001). Given that carriers have strong internal incentives to reduce denied boardings, Garrow et al. (2011) investigate those factors that contribute to denied boardings. They contend that a denied boarding is influenced not only by multiple factors compensation amounts, but also by the accuracy, magnitude, and variability that are associated with no-show forecasts, load factors, and carriers' day of departure operating policies.

Other studies further analyze the influence of service denial on the performance of service providers. Wittman (2014) shows that the involuntary denied boardings by airlines are significantly correlated with higher oversales and service quality complaints from passengers. Lindenmeier and Tscheulin (2008) verify that a denied boarding because of overbooking will induce customer dissatisfaction, which in turn counteracts the positive effect of revenue management. To further understand the negative effect of canceled reservations, Hannigan (1980) explores the origin, nature, and dimensions of consumer complaints in the tourist industry. To prevent negative publicity through word of mouth, service providers adopt certain measures to minimize the negative effects of walking guests (DeKay et al., 2004). Ivanov (2006) suggests that guests with shorter stays must be walked instead of those with longer stays, and transfer the walked guests to another establishment of the same category, or provide their guests with a free room upgrade. Sparks and Fredline (2007) provide suggestions for hospitality industries to mitigate the negative influence of service failure on customer satisfaction and loyalty. When determining compensation levels in overbooking situations, airlines must consider the temporal costs of passengers and ensure that their compensation will satisfy their demands (Park and Jang, 2014). Also, Wilson et al. (1994) examine the legality of the overbooking practice and propose some amenities to placate the denied guests.

Although many studies have investigated the overbooking phenomenon, most of them are conducted from the perspective of service providers either to achieve full utilization of their finite capacity and obtain higher profits or to minimize the negative effects of denied service. Nevertheless, none of these papers has analyzed the service denials that are caused by the overbooking strategy from the customer's perspective. To fill such gap and provide directions for customers when they make reservations, this paper dissects the probability for a denied service when a service provider adopts the overbooking strategy. By considering the popularity of online distribution (Guo et al., 2013a; Ling et al., 2011), we apply our model in an environment in which the service provider applies the overbooking strategy in cooperation with an OTA.

3. Overbooking strategy analysis

3.1. Problem description

We consider a supply chain that comprises a service provider (such as an airline or a hotel) and an OTA. The service provider sells a single type of products with a finite capacity of c at the same price of p through its own distribution channel as well as the online marketing system of the OTA. By cooperating with the OTA, the supply chain gains two sources of customers, namely, t-customers who make reservations from the host distribution channel of the service provider, and w-customers who make reservations from the website of the OTA. Following Ling et al. (2011), we suppose that w-customers have check-in priority when the total demand exceeds the service capacity.

For clarity, we assume that demand is a linear function of the selling price without affecting the results. Specifically, the demand of t-customers is denoted as $D_1=a_1-b_1p+\varepsilon_1$, where $a_1>0$ is the market size, $b_1>0$ is the price elasticity coefficient for t-customer demand, and ε_1 is a stochastic term with zero mean and finite variance. This type of demand structure is widely used in academic studies (Gilbert and Cvsa, 2003; Wang et al., 2004). A nonlinear case is also discussed in the numerical studies in Section 5.

Suppose that the service provider will pay the OTA a unit commission fee, ω, for each product that is sold by the OTA. The commission is usually a percentage of the selling price of the product (Toh et al., 2011). Denote $\omega=\theta p$, where θ is the commission rate. To gain more revenue, the OTA exerts more efforts to generate more sales (Guo et al., 2013a). Denote the effort level as e, which will incur a cost of the OTA, $ke^2/2$, which increases convexly with e and k is the effort cost parameter (Kaya, 2011; Taylor, 2002). Therefore, the demand of the w-customers increases along with the effort level and decreases along with the selling price of the product, i.e., $D_2=a_2-b_2p+e+\varepsilon_2$, where $a_2>0$ is the market size, $b_2>0$ is the price elasticity coefficient for w-customer demand, and ε_2 is a stochastic term with zero mean and finite variance. This type of demand structure is also widely used in academic research (Cachon and Lariviere, 2005; Kaya, 2011).

Therefore, D, which denotes the total demand of the service provider (including t-customers and w-customers), can be written as $D=a_1+a_2-(b_1+b_2)p+e+\varepsilon_1+\varepsilon_2$. By denoting $a=a_1+a_2$, $b=b_1+b_2$ and $\varepsilon=\varepsilon_1+\varepsilon_2$, we can obtain $D=a-bp+e-\varepsilon$. Similarly, ε is a stochastic term with zero mean and finite variance, and follows a distribution over $[A,B]$ with probability distribution function (*pdf*) $f(\cdot)$ and cumulative distribution function (*cdf*) $F(\cdot)$.

In practice, some customers will cancel their reservations or do not show up without notifying the service provider. To maintain its revenue, the service provider will adopt an overbooking strategy with an overbooking pad, l, to hedge against the capacity idleness that is caused by C&NS. We denote the show-up rate of customers with successful reservations as β, which is a stochastic variable with *pdf* $g(\cdot)$ and *cdf* $G(\cdot)$. The value range of β is $[\underline{\beta},\overline{\beta}]$, where $\underline{\beta}$ and $\overline{\beta}$ are the minimum and maximum values of β, respectively.

Overbooking may result in oversales and then denied service. When a denied service becomes inevitable, the service provider must do everything to placate the denied customers. In practice, hotels usually upgrade the reservations of their denied customers to luxury rooms, provide them with free nights of stay, or transfer them to other comparable hotels (Ivanov, 2006). DeKay et al. (2004) suggest that hoteliers, when pressed for explanations by denied customers, should attribute their oversales to the fault of their customers than to the overbooking practices of the hotel. Noone and Lee (2011) suggest that cash-based compensation will yield significantly higher satisfaction ratings than other types of compensations. All of these measures are extensively adopted by companies to repair their reputation and ensure business continuance. We assume that denying a customer will incur a reputation loss of v_1 as well as a monetary loss of v_2 to the service provider.

When the number of customers (including t-customers and w-customers) who make reservations in advance is less than $(c+l)$, the service provider accepts all the orders; otherwise, the service provider accepts $(c+l)$ orders at most. When the actual number of arrivals exceeds the anticipated number on the target date, each denied customer brings a loss of $v=v_1+v_2$ to the service provider. Therefore, the expected profit of the service provider can be expressed as follows:

$$\pi_s = pE_1(\varepsilon,\beta) - vE_2(\varepsilon,\beta) - \theta pE_3(\varepsilon_2,\beta), \tag{1}$$

Where $E_1(\varepsilon,\beta)=E[min\{\beta D,\beta(c+l),c\}]$, $E_2(\varepsilon,\beta)=E[(\beta min\{D,c+l\}-c)^+]$, and $E_3(\varepsilon_2,\beta)=E[\beta D_2]$. The show-up rate, β, is independent from the stochastic term of demand, ε. The first part of Equation (1) represents the revenue that is obtained from customers who are granted the service, the second part represents the loss from the denied customers, and the third part represents the commission fee that is paid to the OTA. As shown in the third part, the service provider prioritizes the w-customers when the number of rooms cannot accommodate all show-up customers. This observation can be attributed to the fact that the service provider prefers to maintain a long-term cooperative relationship with the OTA instead of gaining immediate revenue (Guo et al., 2013a). Similarly, the expected profit of the OTA is:

$$\pi_o = \theta pE_3(\varepsilon_2,\beta) - ke^2\Big/2. \tag{2}$$

3.2. Solution methodology

A Stackelberg game model is adopted to describe the interaction between the service provider and OTA, in which the service provider acts as the leader and the OTA acts as the follower. The service provider determines its optimal overbooking pad and selling price. As a result, the commission for the OTA, which is a percentage of the selling price, is realized. The OTA subsequently determines its optimal effort level according to the commission. The sequence of events is described as follows. (i) The service provider determines the optimal overbooking pad l as well as the selling price p. Then the commission rate for the OTA is known as θp. (ii) The OTA determines its effort level, e, according to the realized unit commission. (iii) The service provider and OTA accept the reservations and all demands are realized on the target date. (iv) The service provider placates the denied customers and gives them monetary compensation if the number of arrivals exceeds the capacity. (v) The OTA receives a commission fee from the service provider according to the contract terms.

The service provider and OTA make decisions to maximize their own expected profits separately. The optimal solution is obtained through a two-step *backward induction*. In the first step, the OTA determines its optimal effort level after being informed of the commission. In the second step, the service provider determines its optimal overbooking pad and the selling price of the product.

Given the selling price of the product, the unit commission can be realized as $\omega=\theta p$. Therefore, the OTA must determine the required effort level to maximize its expected profit. Given that the second-order derivative of Equation (2) with respect to e is negative, Equation (2) is a concave function of e and there is a unique optimal solution to maximize its profit. From the first-order condition on e, the unique optimal effort level e^* is obtained as follows:

$$e^* = \tau\theta p/k \tag{3}$$

where $\tau = \int_{\underline{\beta}}^{\overline{\beta}} yg(y)dy$.

Equation (3) shows that the effort level of the OTA is closely related to the selling price, that is, a higher selling price induces a higher commission under a fixed commission rate θ. As a result, the OTA will exert more effort to generate more sales.

Considering that the OTA will choose its effort level according to Equation (3) in response to a given selling price p, the service provider determines its overbooking pad and selling price to maximize its own expected profit. By substituting Equation (3) into Equation (1), the profit of the service provider is obtained as $\pi_s(l,p)$. Optimal decisions will be obtained by maximizing $\pi_s(l,p)$.

Lemma 1. *The optimal overbooking pad and selling price of the service provider are determined by the following equations,*

$$\int_{\frac{c}{c+l^*}}^{\overline{\beta}} yg(y)dy = \tau p^*/(p^*+v), \tag{4}$$

$$\begin{aligned}
&\frac{\tau v(c+l^*)}{p^*+v} + c\left(1 - G\left(\frac{c}{c+l^*}\right)\right) - \tau\theta\left(a_2 - 2p^*\left(b_2 - \frac{\tau\theta}{k}\right)\right) \\
&\quad + \tau\int_A^N xf(x)dx + \left(cG\left(\frac{c}{c+l^*}\right) - \frac{\tau v M}{p^*+v}\right)F(M) \\
&\quad + \int_N^M \left(\int_{\underline{\beta}}^{\zeta} yg(y)dy\right) xf(x)dx - cF(N) - c\int_N^M G(\zeta)f(x)dx \\
&\quad + \left(a - (2p^*+v)\left(b - \frac{\tau\theta}{k}\right)\right)\int_N^M \frac{\zeta^3}{c} g(\zeta)F(x)dx = 0
\end{aligned} \tag{5}$$

where $M = c + l^* - a + p^*(b - \tau\theta/k)$, $N = c - a + p^*(b - \tau\theta/k)$, and $\zeta = c/(a - p^*(b - \tau\theta/k) + x)$.

The proof for this lemma is given in the Appendix. Even if the distributions of the show-up rate and demand are given, it is improbable to obtain the closed-form solution for the optimal decisions due to the complexity of Equations (4) and (5). It is even possible that the problem is not concave as shown in the Appendix (Proof of Lemma 1). Therefore, we are encouraged to introduce an intelligent algorithm to solve this problem numerically. As an efficient stochastic global search technique, the genetic algorithm can provide the approximate-optimum solution by comparing individual numerical results and without requirements in analytical tractability and concavity (Solnon et al., 2008; Yu et al., 2013; Jiang et al., 2015). Considering the complexity of the problem in the current study and the advantages of genetic algorithm, the following solution methodology is proposed to find the approximate-optimum solution:

- Step 1. **Initialization**. The initial population is randomly generated according to the number of variables and individuals. Two variables are considered in this problem, namely, the overbooking pad l and the selling price p. The number of individuals is randomly generated.
- Step 2. **Selection**. Individual solutions are selected from the existing population according to the fitness value of each individual and are set as the “parents” to breed a new generation. The fitness function is the profit of the service provider, that is, $\pi_s(l,p)$.
- Step 3. **Crossover**. Two different individuals are randomly collocated into a pair of “parents”, and their chromosomes are exchanged with a certain crossover rate to produce a “child” solution. The new “child” solution shares many characteristics of its “parent”.
- Step 4. **Mutation**. For each randomly selected “child” individual, one or some of its vertices are changed with a certain mutation rate to produce the next generation population of chromosomes that differs from the initial generation. Mutation aims to increase diversity in the population.
- Step 5. **Termination**. Steps 2 to 4 are repeated until the satisfactory optimum solutions is obtained, that is, the maximal profit of the service provider generated from the algorithm is fitting in the precision requirement.

The optimal overbooking pad l^* and selling price p^* can be obtained using the above algorithm. By Substituting p^* into Equation (3), the optimal effort level for the OTA is obtained as e^*.

The subsequent section discusses how the probability of a denied service is calculated according to the aforementioned solution.

4. Probability of denied service with successful reservation

Service providers apply the overbooking strategy to increase their occupancy rates and revenues. However, overbooking may result in denied service when the number of arrivals exceeds the available capacity. Such denial of service presents heavy consequences for the denied customers, such as missing an important meeting and rescheduling their work plans. To help these customers understand the overbooking strategy and explore the probability for failing to receive the reserved service, this section analyzes the overbooking decision from the customers' perspective.

After determining the optimal overbooking pad, l^*, the probability for n customers to be denied, P_n, can be expressed as follows

$$P_n = \sum_{i=c}^{c+l^*} \left(p_i \cdot P_i^n\right), \tag{6}$$

where p_i is the probability for the service provider to accept a number of i reservations, and P_i^n is the probability for the service provider to deny n customers on the target date while accepting i reservations, where $n=0,1,\cdots,l^*$.

This result shows that a higher overbooking pad results in a larger probability of a denied service. Given that the demand of customers, D, and the show-up rate, β, are continuous variables, we apply the rounding-off method to calculate p_i and P_i^n as follows:

$$p_i := Prob\{i - 0.5 \le D < i + 0.5\} = F(i+0.5) - F(i-0.5),$$

$$\begin{aligned}
P_i^n &:= Prob\{c + n - 0.5 \le \beta i < c + n + 0.5\} \\
&= G\left(\frac{c+n+0.5}{i}\right) - G\left(\frac{c+n-0.5}{i}\right),
\end{aligned}$$

where $F(\bullet)$ and $G(\bullet)$ are the *cdf* of ε and β, respectively.

Based on probability of denied service P_n, the expected number of denied customers, n_E, can be obtained as $n_E = \sum_{n=1}^{l^*} nP_n$. The denied rate of customers with successful reservations, r_E, and customer-service level, ρ_E, are then calculated as $r_E = n_E/(c+l^*)$ and ρ_E=1−r_E. Parameters n_E, r_E, and ρ_E reflect the probability of denying from another perspective to further understand the overbooking strategy of the service provider. Specifically, a higher probability to be denied results in a smaller number of expected denied customers, lower denied rate, and lower customer-service level.

The subsequent section presents some numerical examples for clarification of the problem.

5. Numerical examples

To illustrate that the assumption of linear demand function will not affect our findings, Section 5.1 presents a numerical example based on the linear demand functions, whereas Section 5.2 presents the results based on nonlinear demand functions.

We take Southwest Airlines (www.southwest.com), which cooperates with Expedia.com in seat selling, as an example. Southwest Airlines uses Boeing 737-700 aircraft, which seats 143 passengers in an all-economy configuration; that is, capacity c=143. The commission rate θ for Expedia.com is set as 18%, the effort cost parameter k is supposed to be 0.5, and the loss in its reputation for each denied customer is defined as v_1=400. Following previous research, the show-up rate of customers with reservations, β, is supposed to be uniformly distributed over [0.9,1] (Dong and Ling, 2015; Kasilingam, 1997; Popescu et al., 2006). As shown in the Southwest Airlines website, the average value for the highest ticket prices of different flights from New York to Los Angeles on December 12, 2015 is US$645, whereas the average value of the lowest prices is US$288. Assume that the demands for t-customers and w-customers are 100(500) and 40(450) at price US$645(US$288), respectively, when customer C&NS are ignored. These data will be used to estimate the parameters of demands in the numerical examples.

5.1. Linear case

Based on the ticket prices and demands given above, the market sizes and price elasticity coefficients can be estimated, and then the demands of t-customers and w-customers are computed as D_1=823−1.12p+ε_1 and D_2=781−1.15p+e+ε_2, respectively. This type of demand structure is widely used in academic research to reduce the complexity of the model (Wang et al., 2004; Cachon and Lariviere, 2005; Kaya, 2011). The total demand is then computed as D=1604−2.27p+e+ε, where the stochastic term ε follows a Normal distribution with a mean value of μ=0 and a standard variance of σ=δ(1604−2.27p+e) with $\delta = 1/3$ (Kaya, 2011).

Based on the genetic algorithm in Section 3.2, Table 1 shows the optimal overbooking pads under different values of monetary compensation v_2.

Table 1 shows that monetary compensation has a significant influence on the optimal overbooking pad. As the monetary compensation that is paid to denied customers increases, the service provider decreases its overbooking pad to avoid reputation and monetary losses.

Table 1
Optimal overbooking pads in the linear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
l^*	10	6	4	3	3	2	2	2

Based on the optimal overbooking pads in Table 1, the probabilities of denied service in Table 2 are obtained by following Equation (6). The corresponding expected number of denied customers, denied rate, and customer-service level are presented in Table 3.

Table 2 shows that the denied service probability decreases along with monetary compensation, which indicates that customers can enjoy their reserved services at a higher probability when the promised monetary compensation is high. As the monetary compensation increases, the service provider sets a lower overbooking pad and to accommodate all arrivals with a higher probability. In particular, when $v_2 \geq 30p$, the service provider will not adopt the overbooking strategy and all customers can enjoy their reserved services without worrying about being denied by the service provider.

Table 3 shows that both the expected number of denied customers and the expected denied rate are decreasing along with monetary compensation, whereas the customer-service level increases along with monetary compensation. As the monetary compensation increases, the service provider faces larger revenue losses by denying a customer. Therefore, the service provider must set a lower overbooking pad to reduce the expected number of denied customers and denied rate.

The above findings have the following implications. First, the service provider can adjust its overbooking decision according to the realized customer-service level. Specifically, a lower overbooking pad should be set when the realized customer-service level is lower than expected. Otherwise, the service provider should set a higher overbooking pad to increase its occupancy rate. Second, customers can deduce their probability of enjoying their reserved services by observing the monetary compensation that is announced by the service provider. For example, if the monetary compensation is twice larger than the selling price, then the expected probability of a denied service is 0.285%, which is less than one-fifth of 1.621% when no monetary compensation is promised. Furthermore, when the promised monetary compensation is five times larger than the selling price, the customers can have a 99.9% probability of enjoying their reserved service.

5.2. Nonlinear case

This section presents the numerical results of the nonlinear demand models. Following the previous literature, we assume that demand is functioned as $D_1 = a_1p^{-b_1} + \varepsilon_1$ and $D_2 = a_2p^{-b_2} + e + \varepsilon_2$ (Guo et al., 2013b; Wang et al., 2004). By re-estimating the market size and price elasticity coefficients according to the

Table 2
Denied service probability in the linear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
P_0	52.46%	71.62%	81.64%	86.78%	86.79%	92.00%	92.01%	92.02%
P_1	5.14%	5.23%	5.29%	5.31%	5.31%	5.34%	5.33%	5.33%
P_2	5.11%	5.20%	5.25%	5.28%	5.27%	2.66%	2.66%	2.65%
P_3	5.08%	5.17%	5.22%	2.63%	2.63%	–	–	–
P_4	5.04%	5.14%	2.60%	–	–	–	–	–
P_5	5.01%	5.10%	–	–	–	–	–	–
P_6	4.98%	2.54%	–	–	–	–	–	–
P_7	4.95%	–	–	–	–	–	–	–
P_8	4.92%	–	–	–	–	–	–	–
P_9	4.88%	–	–	–	–	–	–	–
P_{10}	2.43%	–	–	–	–	–	–	–
Sum	1	1	1	1	1	1	1	1

Table 3
Expected number of denied customers and denied rate in the linear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
n_E	2.480	0.925	0.419	0.238	0.237	0.107	0.107	0.106
r_E	1.621%	0.621%	0.285%	0.163%	0.162%	0.074%	0.074%	0.073%
ρ_E	98.379%	99.379%	99.715%	99.837%	99.838%	99.926%	99.926%	99.927%

Table 4
Optimal overbooking pads in the nonlinear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
l^*	12	6	4	3	3	2	2	2

aforementioned prices and demands, we compute the demands as D_1=$(4.16\times10^7)p^{-2}$+ε_1 and D_2=$(1.07\times10^{10})p^{-3}$+$e$+$\varepsilon_1$. Furthermore, the total demand can be computed as D=(4.16×10^7) p^{-2}+$(1.07\times10^{10})p^{-3}$+$e$+$\varepsilon$.

Similarly, ε is Normal distributed with a mean value of 0 and a standard variance of $\sigma = (1.39 \times 10^7)p^{-2} + (3.57 \times 10^9)p^{-3} + e/3$. The optimal overbooking pads and the probabilities of denying under different values of v_2 are given in Tables 4 and 5, whereas the expected number of denied customers, denied rate and customer-service level are shown in Table 6.

The tables for linear and nonlinear demand models present similar results. Specifically, the optimal overbooking pad, expected number of denied customers, and expected denied rate all decrease along with monetary compensation, whereas customer-service level increases along with monetary compensation.

6. Conclusions

6.1. Findings and managerial implications

The overbooking strategy will help service providers increase the utilization of their finite capacity, but can also result in service denial when the actual C&NS does not reach its expected level and when the number of arrivals exceeds the available capacity. Denied service will damage the reputation and revenue of service providers as well as bring immeasurable losses to some denied customers. To understand this strategy from the perspective of customers, this paper analyzes the probability for those customers with reservations to be denied of service by referring to the optimal decisions that result from the game between a service provider and an OTA.

The optimal overbooking pad of the service provider decreases along with the announced monetary compensation that is paid to the denied customers with reservations. A higher monetary compensation always results in a higher probability for customers to enjoy their reserved service. Table 2 shows that the service provider has a 92% probability to accept all arrivals when the promised monetary compensation is five times larger than the selling price, but only has a 52.46% probability to accept all arrivals when the monetary compensation is zero.

These findings have significant academic and practical implications. From the academic perspective, this paper is the first, to our best knowledge, to discuss the overbooking strategy of service providers from the perspective of customers, that is, this paper explores the probability of denying caused by overbooking. Previous studies have mostly focused on identifying the most appropriate overbooking pads for service providers. However, this paper investigates the overbooking strategy of service providers from a new perspective.

This paper provides useful advice to both service providers and customers. First, customer-service level is one of levers for assessing the service quality of service providers. Therefore, service providers must adjust their overbooking pad according to the realized customer-service level. Specifically, if the customer-service level under an overbooking pad is lower than expected, then service providers must lower their overbooking pad in the next selling period. Otherwise, setting a higher overbooking pad will be reasonable to increase the occupancy rate.

Second, Toh and Dekay (2002) suggest that when making reservations, the customers must be informed about no-show penalties to reduce the no-show probability. However, the current paper suggests that the service providers should announce high monetary compensations for denied customers to guarantee these customers that their reservations will be granted.

Third, customers can estimate the probability of denied service according to the monetary compensation that is announced by service providers before making a deal. The numerical example shows that when the value of monetary compensation for the denied customers is five times larger than the selling price, the customers have a 99.9% probability of enjoying their reserved service. In this manner, customers can select those service providers that can guarantee their reservations and respect their schedules.

6.2. Limitations and future research

Although this paper is the first to analyze the overbooking strategy from the customer perspective, its scope is limited, thereby providing opportunities for further research. First, this paper only examines the probability of a denied service under a static overbooking pad, and future studies can examine such probability when a dynamic overbooking strategy is applied. Second, we merely assume that a denied service incurs a quantified reputation loss for the service provider. Future studies can consider the influence of denials on market demand. Third, given the intense competition among service providers with similar services and OTAs, the decisions in a network environment with multiple service providers and OTAs must be investigated.

Table 5
Denied service probability in the nonlinear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
P_0	27.30%	63.83%	76.67%	83.22%	83.22%	89.86%	89.86%	89.86%
P_1	6.33%	6.58%	6.67%	6.71%	6.71%	6.76%	6.76%	6.76%
P_2	6.33%	6.58%	6.67%	6.71%	6.71%	3.38%	3.38%	3.38%
P_3	6.33%	6.58%	6.66%	3.36%	3.35%	–	–	–
P_4	6.33%	6.57%	3.33%	–	–	–	–	–
P_5	6.32%	6.57%	–	–	–	–	–	–
P_6	6.32%	3.29%	–	–	–	–	–	–
P_7	6.32%	–	–	–	–	–	–	–
P_8	6.32%	–	–	–	–	–	–	–
P_9	6.32%	–	–	–	–	–	–	–
P_{10}	6.31%	–	–	–	–	–	–	–
P_{11}	6.31%	–	–	–	–	–	–	–
P_{12}	3.16%	–	–	–	–	–	–	–
Sum	1	1	1	1	1	1	1	1

Table 6
Expected number of denied customers and denied rate in the nonlinear case.

v_2	0	p	$2p$	$3p$	$4p$	$5p$	$6p$	$7p$
n_E	4.549	1.183	0.533	0.302	0.302	0.135	0.135	0.135
r_E	2.935%	0.794%	0.363%	0.207%	0.207%	0.093%	0.093%	0.093%
ρ_E	97.065%	99.206%	99.637%	99.793%	99.793%	99.907%	99.907%	99.907%

Acknowledgments

This work was supported by the National Natural Science Foundation of China (No. 71501174; 71271197; 71520107002), the China National Tourism Administration (No. 15TAAK009), the fund for young tourism experts of Anhui Provincial Tourism Administration (AHLYZJ201505), and the Fundamental Research Funds for the Central Universities. The authors would also like to thank Editor Sveinn Vidar Gudmundsson and two anonymous referees for their comments and suggestions.

Appendix

Proof of Lemma 1. Define $M = c + l - a + p(b - \tau\theta/k)$, $N = c - a + p(b - \tau\theta/k)$, and $\zeta = c/(a - p(b - \tau\theta/k) + x)$. To maximize $\pi_s(l,p)$, the first-order derivations for l and p can be calculated as follows.

$$\frac{\partial \pi_s}{\partial l} = \left(\tau p - (p+v)\int_{\frac{c}{c+l}}^{\overline{\beta}} y g(y) dy\right)(1 - F(M)),$$

$$\begin{aligned}\frac{\partial \pi_s}{\partial p} = {} & \frac{\tau v(c+l)}{p+v} + c\left(1 - G\left(\frac{c}{c+l}\right)\right) - \tau\theta\left(a_2 - 2p\left(b_2 - \frac{\tau\theta}{k}\right)\right) \\ & + \tau\int_A^N x f(x) dx + \left(cG\left(\frac{c}{c+l}\right) - \frac{\tau v M}{p+v}\right)F(M) \\ & + \int_N^M \left(\int_{\underline{\beta}}^{\zeta} y g(y) dy\right) x f(x) dx - cF(N) \\ & - c\int_N^M G(\zeta) f(x) dx \\ & + \left(a - (2p+v)\left(b - \frac{\tau\theta}{k}\right)\right)\int_N^M \frac{\zeta^3}{c} g(\zeta) F(x) dx.\end{aligned}$$

To verify whether the expected profit of the service provider is jointly concave in l and p, the second-order derivation of the profit should be calculated. They are given as follows.

$$R := \frac{\partial^2 \pi_s}{\partial l^2} = -\frac{c^2(p+v)}{(c+l)^3} g\left(\frac{c}{c+l}\right)(1 - F(M)),$$

$$\begin{aligned}S := \frac{\partial^2 \pi_s}{\partial p^2} = {} & -2\theta\tau\left(\frac{\tau\theta}{k} - b_2\right) - \frac{2\tau v(\tau\theta/k - b)F(M)}{p+v} \\ & - \frac{\tau\theta/k - b}{c}\int_N^M \zeta^3 g(\zeta)\left(2F(x) + (p+v)\left(\frac{\tau\theta}{k} - b\right)f(x)\right)dx,\end{aligned}$$

$$T := \frac{\partial^2 \pi_s}{\partial l \partial p} = \frac{\tau v}{p+v}(1 - F(M)).$$

Obviously, R is negative. Furthermore, we are able to find that if the following conditions hold, $S<0$ and $T^2 - RS < 0$ can be realized.

$$\begin{aligned}\Delta_1 := {} & \frac{\tau\theta/k - b}{c}\int_N^M \zeta^3 g(\zeta)\left(2F(x) + (p+v)\left(\frac{\tau\theta}{k} - b\right)f(x)\right)dx \\ & + 2\theta\tau\left(\frac{\tau\theta}{k} - b_2\right) + \frac{2\tau v(\tau\theta/k - b)F(M)}{p+v} > 0, \quad \text{and}\end{aligned}$$

$$\begin{aligned}\Delta_2 := {} & (1 - F(M))\left(\frac{\tau v}{p+v}\right)^2 - \frac{c^2(p+v)}{(c+l)^3} g\left(\frac{c}{c+l}\right)\left(2\theta\tau\left(\frac{\tau\theta}{k} - b_2\right)\right. \\ & \left. + \frac{2\tau v(\tau\theta/k - b)F(M)}{p+v}\right) \\ & - \frac{c(p+v)(\tau\theta/k - b)}{(c+l)^3} g\left(\frac{c}{c+l}\right)\int_N^M \zeta^3 g(\zeta)\left(2F(x)\right. \\ & \left. + (p+v)\left(\frac{\tau\theta}{k} - b\right)f(x)\right)dx < 0.\end{aligned}$$

Consequently, the optimal solution of (l,p) are constrained by Equations (4) and (5), and the solutions are unique if $\Delta_1>0$, $\Delta_2<0$, under which the profit of the service provider is jointly concave in the overbooking pad and selling price.

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