

The Economics of Service Upgrades

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Many service providers offer different service classes (e.g., first class, second class). Because the capacity of each class is set in advance, providers may end up with unfilled first-class capacity at the time of service delivery. When this happens, providers often upgrade some of their customers from a lower service class to a higher one. One way in which service providers manage upgrades is by selling, in advance, tickets that entitle the holder to an upgrade if space becomes available in a higher service class. This article investigates the circumstances under which upgradeable tickets are profitable, how to price them, and how many to issue. Upgradeable tickets increase the provider's profits when the probability of obtaining full price for first-class service is sufficiently high. With upgradeable tickets, more of the available capacity can be reserved for potential customers who are willing to pay a high price for high-end service.

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Service providers including airlines, train operators, hotels, sports stadiums, and performing arts companies

typically offer different service classes (e.g., first class, business class, economy class). Some of the upscale units may go unsold because of uncertain demand and the need to allocate capacity to each service class prior to demand realization. Many companies upgrade customers from lower-class service to upper-class service, using the unsold upper-class units as a “cheap” way to reward loyal customers (Deighton and Shoemaker 2001) and to mollify complaining ones (Garrett 1994). Upgrades are common in many industries:

- Hotels routinely upgrade customers to better accommodations. For example, InterContinental Hotels have an optional upgrade program with upgrades to Junior Suite, Club Intercontinental Floor, and Business Room.¹
- Cruise lines offer many opportunities to upgrade. In the recent past, it was not uncommon to receive an upgrade simply by asking for it. Today, cruise lines such as Carnival and Norwegian centralize upgrade decisions with their revenue management departments or reward upgrades on a case-by-case basis

1. See <http://www.hotelexecutive.com/archives/2002/november/20.htm>.

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following authorization from high-ranking executives.²

- Trains and airlines provide other examples of industries using upgrades extensively.

With the advent of information technology, a greater number of service providers are employing sophisticated upgrade programs, which are becoming an important marketing tool. For example, Delta Airlines now has screen displays in their departure gates that are connected to their central reservation system. In addition to flight status and boarding information, Delta uses these screens to offer, when seats are available, upgrades to customers waiting in the gate area. A typical offer might be to upgrade customers that hold more expensive second-class tickets (e.g., class Y, G, or O tickets) to first class.

Given the prevalence and growing importance of upgrading, it is surprising that academic research has not yet concentrated on this issue. The prevalent view in both the popular business press and conceptual writings on this issue is that upgrades are a cheap method of rewarding loyal customers. This view, however, does not explain all that is currently happening with upgrade programs. For example, although Delta has a specific upgrade program for frequent flyers, the upgrade offers made at the gate area typically exclude frequent flyers that do not hold expensive tickets in the eligible classes (i.e., if they purchased a cheap ticket). Nor can the relationship reward view explain why upgrade availability should be restricted to specific fare classes.

This article examines upgrade programs as a tool to assist in the pricing of fixed-capacity services facing uncertain demand. This approach to upgrades both differs from and complements the relationship reward approach. In our view, many of the design choices of upgrade programs are driven by trade-offs related to these pricing issues. We suggest that service providers can implement upgrades by advance selling a probabilistic service class of “upgradeable tickets” that entitle the holder to an upgrade if higher-class units are available at the time of service delivery. These upgradeable tickets correspond to upgrade offers that are restricted to certain fare classes. We consider a model with strategic consumers who take into account the upgrade opportunities when deciding which ticket to purchase. Thus, offering upgrades and restricting them to certain fare classes changes the product line pricing and capacity allocation issues facing the service provider. The model explores these issues and shows when upgradeable tickets are profitable, how to price them, and how many upgradeable tickets to issue. The model results show which aspects of current upgrade policies are consistent with optimal behavior and which are not.

2. See <http://www.cruisemates.com/articles/consumer/upgrades.cfm>.

The research in this article provides managerial insights showing that offering upgradeable tickets will always be more profitable than reserving first-class tickets for full-price customers who may or may not show up. Given the choice between reserving first-class capacity for late-arriving customers with or without offering upgradeable tickets, the first alternative is more profitable. However, service providers can also advance sell first-class capacity at a discounted price. Taking this alternative into account, we find that offering upgradeable tickets is more profitable than advance selling first class at a discounted price, if the probability of selling the upper-class capacity at full price is sufficiently high. This result is counterintuitive because salvaging unsold upper-class capacity appears to be more useful when this probability is low rather than high. However, when the probability of selling upper-class capacity at full price is low, it is more profitable to advance sell first-class capacity. The reason is that advance buyers are willing to pay a higher price for the guaranteed first-class service than for the upgradeable tickets. Hence, selling upgradeable tickets is more profitable than advance selling first class only if the opportunity cost of offering such a guaranteed service is very high, which occurs when the seller has a high probability of selling the upper-class ticket at full price (rather than when the seller is unlikely to do so).

These results can guide service providers in choosing among the three policies of selling first-class capacity: advance selling first class, reserving first class, or using upgradeable tickets. The profitability of each policy depends on the probability of selling first class at full price. When this probability is very small, advance selling is the most profitable policy and reserving is the least profitable. When this probability is intermediate, then offering upgradeable tickets becomes the most profitable policy and reserving is the least profitable. Finally, if this probability is sufficiently large, selling upgradeable tickets is the most profitable policy, but advance selling becomes the least profitable.

Before presenting the model used to obtain these results, we review the extant literature that relates to service upgrades.

RELATED RESEARCH

Surprisingly, there is little research that looks specifically at the issue of service upgrades.³ Previous research

3. In the operations literature, there are a few articles that discuss “upgrades” in which consumers purchase more expensive service class than they would like (first class instead of business) because the service classes they prefer are fully booked. (Brumelle et al. 1990; Pfeifer 1989; Zhao and Zheng 2001). This notion of upgrades, however, bears similarities to the notion of “bait and switch” in the marketing literature (Gerstner and Hess 1990; Wilkie, Mela, and Gundlach 1998) and is different from the commonly understood notion of upgrades as used in this article.

on upgrades concentrated on product upgrades, emphasizing technological companies that sell upgraded versions of products. Technology companies often offer upscale versions of a basic product—extra features, better performance, more services. Software suppliers charge lower prices for upgrades than for new versions. One justification for this strategy is that customers who already own a version of a product are less likely to move to a newer version. Existing customers who upgrade pay a lower price than do new customers (Fudenberg and Tirole 1988). The driving factor behind product versioning is the opportunity to price discriminate based on differences in consumers' willingness to pay. Although differences in consumers' willingness to pay certainly play a role in service upgrades, the main motivation for offering service upgrades is to use a fixed capacity better when facing uncertain demand and not to price discriminate.

The most relevant literature on the topic of service upgrades is the literature on revenue management, especially that which examines overbooking and contingent pricing. Revenue management addresses the problem of optimal allocation of a fixed capacity of seats to different booking classes (e.g., full and discounted fares; for a comprehensive overview of revenue management, see McGill and Van Ryzin 1999; Weatherford and Bodily 1992). One of the possible consequences of revenue management systems is overbooking—selling tickets for more seats than are actually available. See Rothstein (1985) and Chatwin (1993) for research on the history of overbooking, and see Biyalogorsky et al. (1999), Chatwin (1999), and Subramanian, Stidham, and Lautenbacher (1999) for recent developments in research on overbooking. The central issue in overbooking is how to best use the available capacity if demand outstrips the supply. As a result, overbooking models balance the cost of missed revenue from customers with reservations who do not show up, thus leaving empty seats, against the cost of compensating customers with confirmed seats who are bumped from an overbooked flight. Biyalogorsky et al. (1999) and Biyalogorsky and Gerstner (2004) showed that under such conditions, a seller with limited capacity facing uncertain demand can profit from contingent pricing arrangements (such as cancellation clauses and standby discounts) even if all customers show up. Under such arrangements, price is contingent on whether a higher price can be obtained within a specified period. If a higher price is obtained and demand exceeds capacity, service is denied to low-paying customers, who then receive previously arranged compensation.

Overbooking and contingent pricing models are useful when realized demand exceeds allocated capacity. However, realized demand can turn out to be lower than allocated capacity. The literature described above does not

explore methods for salvaging capacity when realized demand is lower than allocated capacity. This article fills that gap by showing that the use of upgradeable tickets can assist in salvaging and managing available capacity of service classes while increasing overall profitably.

Shugan and Xie (2000, 2004) and Xie and Shugan (2001) showed that sellers can use advance selling to extract surplus from consumers who are unsure of their valuation of the service at the time of purchase. Advance selling can be more profitable than spot selling because separating purchase and consumption creates buyer uncertainty concerning the product's value at the time of consumption. This uncertainty negates the information advantage buyers possess under spot selling from their private knowledge of their own valuations. This article shares some characteristics with extant advance-selling literature, as selling upgradeable tickets also requires that buyers purchase services before consumption. However, it focuses on the effects of providers' uncertainty regarding future demand, rather than on buyers' uncertainty concerning valuations. By offering upgradeable tickets, the provider does not simply sell the same service in advance; rather, the provider creates a new service class—a probabilistic service class.

In summary, this article addresses an important gap in the existing literature on service pricing with fixed capacity of upper- and lower-service classes facing uncertain demand. It is the first model that considers the use of upgrades as a contingent mechanism to ameliorate situations in which the realized demand for upper-class service is lower than allocated capacity. Recently, the use of upgrades, especially in the airline industry, has been going through a transformation. Upgrades have become increasingly common, and different ways of handling them have been adopted. The optimal number of upgradeable tickets and their pricing are of interest, but the literature has not yet offered a solution. This article suggests a profitable method for the allocation and pricing of upper-class capacity using upgradeable tickets.

THE MODEL

The model is designed to investigate when upgrading is optimal given that multiple classes exists, and therefore we assumed for simplicity that multiple classes is given exogenously and do not include an analysis on when it is optimal to offer multiple classes or only a single class. We consider a service provider (referred to as *provider*) that sells one unit of first-class service and one unit of second-class service.⁴ Consumers are willing to pay more for first

4. In a subsequent section, we analyze the general N unit case.

class than for second class, and there are two consumer types:

- High-value consumers (Highs) are customers willing to pay full price, V_H , for first class and V_2 for second class.
- Low-value consumers (Lows) are customers willing to pay an intermediate price, V_M , for first class and V_L for second class.

Highs are willing to pay more than Lows for the same class of service.

The demand for the perishable service is modeled using a two-period setting, assuming as in Belobaba (1987) that Lows enter the market in Period 1 and Highs in Period 2. Lows exit the market at the end of the first period if they are unable to purchase the service at a price equal to or below their willingness to pay.⁵ Assuming that there are at least two Lows in the market during the first period, the provider can always choose to sell the second-class seat at price V_L and the first-class at price V_M in Period 1. The demand from Highs during the second period is uncertain and limited to a single High who may appear with a known probability of q ($0 < q < 1$).

The provider sells first-class tickets that provide access to first-class service and second-class tickets that provide access to second-class service. The provider can also sell upgradeable tickets that guarantee access to second-class service with an option of upgrading to first class if first-class slots remain unsold at the end of Period 2. Subsequently, conditions under which the provider earns higher profits by offering upgradeable tickets (in addition to first- and second-class tickets) are examined. The discount factor between the two periods is assumed to be equal to 1 (because it is not crucial to the reasoning regarding the usefulness of upgradeable tickets).

No Upgradeable Ticket

In this case, the provider sells the second-class ticket in Period 1 for V_L . The provider has two options in selling the first-class ticket: The first strategy is to advance sell the first-class ticket for V_M in Period 1 and make a profit of $V_L + V_M$. The second strategy is to reserve the first-class unit for sale in Period 2 for a price of V_H and make an expected profit of $V_L + qV_H$. We further assume that the relative attractiveness of first versus second class for Highs is higher than that for Lows, $\frac{V_H}{V_2} > \frac{V_M}{V_L}$.⁶ Clearly, the second

5. This assumption helps simplify the analysis. The spirit of the results does not change if we alternatively assume that Lows stay in the market on the second period with some positive probability.

6. Another possible strategy is to advance sell first-class service to a Low at price V_M and reserve second-class service for a High on the second period with the expected profits of qV_2 . This alternative can be optimal

strategy is more profitable than the first strategy if $q > \frac{V_M}{V_H} \equiv q_{NU}$. Therefore, the expected profits without upgradeable tickets are

$$\Pi = \begin{cases} V_L + V_M & \text{if } q < q_{NU} = V_M / V_H \\ V_L + qV_H & \text{otherwise} \end{cases} \quad (1)$$

Upgradeable Ticket

In this case, the provider sells an upgradeable ticket in Period 1 and reserves the first-class unit for sale in Period 2. An upgradeable ticket allows a customer to enjoy first-class service if the first-class unit remains unsold at the end of Period 2; otherwise, the customer will receive the second-class service.

With the upgradeable ticket, the probability of receiving first-class service by a Low is $1 - q$, so the maximum willingness to pay of a Low for this type of ticket is⁷

$$P_U = qV_L + (1 - q)V_M. \quad (2)$$

Equation 2 can be expressed as $P_U = V_M - q(V_M - V_L)$, revealing that the price of upgradeable tickets decreases with q . This suggests that when upgradeable tickets are offered, the Low trades off between the price of upgradeable tickets and the chance of getting upgrades. A small q implies a low probability for the High-type customers to arrive and a high probability for the Low-type customers holding upgradeable tickets to enjoy the first-class service. Hence, upgradeable tickets are more expensive (i.e., close to V_M) when q is small. For the same reason, upgradeable tickets are less expensive (i.e., close to V_L) when q is large because a large q implies a low probability for a Low to get upgrades.

The provider receives P_U for the upgradeable ticket and V_H for first class if a High appears. The expected profit is

$$\Pi_U = P_U + qV_H \quad (3)$$

(expected profit under upgradeable tickets).

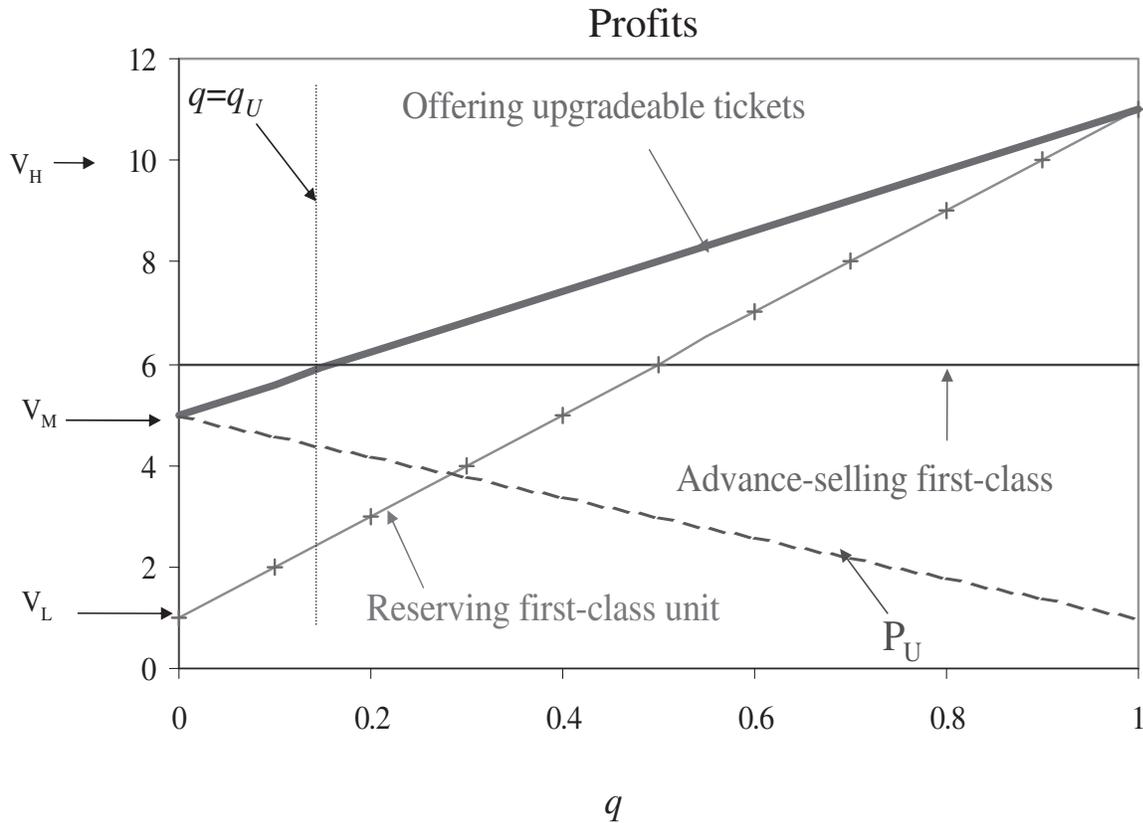
Comparing Equation 3 with Equation 1, Result 1 follows.

Result 1: Upgradeable tickets increase the provider's profit if the probability of obtaining full price for

only if Highs are not willing to pay a sufficiently higher price for the first-class service. Because such a strategy is not observed in practice, we do not analyze it in the body of the article and assume that $V_H/V_2 > V_M/V_L$. This condition means that the relative attractiveness of first-class service compared with second-class service is higher for Highs than for Lows. We thank an anonymous referee for pointing out this issue.

7. Assuming the Low is risk neutral.

FIGURE 1
Profits Under Different Selling Strategies
 ($V_L = 1, V_M = 5, V_H = 10$)



first class is sufficiently high so that Condition 4 holds.

$$q > \frac{V_L}{V_H - (V_M - V_L)} \equiv q_U. \quad (4)$$

Offering upgradeable tickets (i.e., the thickest line in Figure 1) is always more profitable than reserving first-class tickets for sale in Period 2 (i.e., the second strategy under no upgrades, indicated by the “+” line in Figure 1). This is because under both strategies, the seller’s expected profit from the High is qV_H . However, the expected profit from the Low is P_U if the seller offers upgradeable tickets but V_L if the seller reserves the first-class ticket for sale in Period 2. Clearly, the former is more profitable than the latter because the linear combination $P_U = qV_L + (1 - q)V_M$ is larger than V_L , given $q > 0$.

Figure 1 also shows that offering upgradeable tickets is more profitable than advance selling the first-class ticket if the probability of obtaining full price for first class, q , is sufficiently large ($q > q_U$). The upgrade strategy is profitable because it allows the service provider to (a) charge a higher price ($P_U > V_L$) to the low-value customers and (b) keep the option of selling the first-class ticket at a high price, V_H , to high-value customers. The downside of selling an upgradeable ticket, when compared to advance selling first-class tickets, is that the price of upgradeable tickets is smaller than the price that could be obtained from advance selling the first-class ticket to Lows ($P_U < V_M$). This is because Lows are willing to pay a higher price for a guaranteed rather than a probabilistic upper-class service. As a result, selling upgradeable tickets enhances profit only when the opportunity cost of offering guaranteed upper-class service to Lows is high, which happens if the probability of selling the first-price ticket at full price is

TABLE 1
Profit Under Different Policies ($V_L = 100$, $V_M = 300$, $V_2 = 200$, $V_H = 800$)

<i>Probability of Selling First Class at Full Price</i>	<i>Policy for Selling First Class</i>	<i>Seller's Profits</i>	
Small ($q = 0.10$)	Advance selling	400	Highest
	Reserving	180	Lowest
	Upgradeable tickets	360	Intermediate
Midrange ($q = 0.25$)	Advance selling	400	Intermediate
	Reserving	300	Lowest
	Upgradeable tickets	450	Highest
Large ($q = 0.75$)	Advance selling	400	Lowest
	Reserving	700	Intermediate
	Upgradeable tickets	750	Highest

sufficiently high ($q > q_U$). The upgradeable ticket is similar in some respects to a “put option” for selling the upper-class at full price if a full-price customer shows up, and having this option is very valuable when the probability that this customer will show up is high.

Equation 1 implies that without upgradeable tickets, the provider will sell first class for a full price, V_H , only if $q > q_{NU} = \frac{V_M}{V_H}$. Equation 4 implies that with upgradeable tickets, the provider will sell first class for a full price (and offer upgradeable ticket to Lows) if $q > q_U = \frac{V_L}{V_H - (V_M - V_L)}$. It is easy to show that $q_U < q_{NU}$. Result 2 follows.

Result 2: When offering upgradeable tickets, a service provider is more likely to reserve first class for full-fare customers.

An example presented in Table 1 illustrates how the relative attractiveness of the three policies for selling first class (advance selling, reserving, and upgradeable tickets) depends on the probability of selling first class at full price. If this probability is small ($q = 0.10$), then advance selling is the most profitable policy and reserving is the least profitable. If this probability is intermediate ($q = 0.25$), then offering upgradeable tickets is the most profitable policy and reserving is the least profitable. Finally, if this probability is sufficiently large ($q = 0.75$), then offering upgradeable tickets is the most profitable policy but advance selling is the least profitable one.

THE GENERAL N UNITS CASE

The previous discussion focused on the profit improvement generated by a single upgradeable ticket by examining a basic case in which service providers had only one unit of each service class for sale. In this section, a more general case in which service providers offer multiple units of both first- and second-class service is considered.

This extension is important because the assumption of multiple units introduces an interesting complication: service providers can now use yield management to deal with demand uncertainty. Put another way, service providers are able to maximize profits by reserving the optimal number of first-class units for selling to Highs in Period 2, while selling the rest of the first-class units to Lows at lower prices in Period 1. An examination of the profit impact of upgradeable tickets when yield management is used to optimally allocate capacity in markets with demand uncertainty follows.

To address these issues, consider a provider with N_1 units of first-class service and N_2 units of second-class service, where $N_2 \geq N_1$. As before, demand by Lows in the first period is assumed sufficiently high, so advance selling the entire first-class capacity in Period 1 (all $N_1 + N_2$ units) is possible. The number of Highs that show up in Period 2 is a random variable H with a cumulative distribution function of $F(h) = \text{Prob}(H \leq h)$ and a probability mass function of $p(h) = \text{Prob}(H = h) = F(h) - F(h - 1)$. Upgrades to first-class service are randomly allocated to holders of upgradeable tickets if first-class slots remain unsold at the end of Period 2. All other assumptions of the basic model remain unchanged.

We first consider when upgradeable tickets will be offered in the multiple-units case and then show that the results of the basic single-unit case extend to the multiple-unit case.

Let b be the number of first-class units reserved for sale in Period 2. $N_1 - b$ units are sold to Lows in advance in Period 1 at a price of V_M . Let Π_U and Π denote the expected profit with and without upgradeable tickets, respectively. For any given number of reserved units b ,

$$\Pi(b) = V_L N_2 + V_M (N_1 - b) + V_H \min \{h, b\} \quad (6)$$

$$\Pi_U(b) = V_L (N_2 - N_2^U) + P_U N_2^U + V_M (N_1 - b) + V_H \min \{h, b\}.$$

It is easy to see that the provider gains $P_U - V_L$ for each upgradeable ticket sold. Recall that P_U is a linear combination of V_L and V_M , with the probability of receiving an upgrade being the weight on V_M . This probability is greater than zero for all $b > 0$ (i.e., if the provider reserves any first-class unit for sale in Period 2). Therefore, $P_U > V_L$ for all $b > 0$, and it is profitable for the provider to sell upgradeable tickets (at least one) when any first-class units are reserved for sale in Period 2. The only case in which upgradeable tickets do not improve profits is when no first-class units are reserved for Period 2 because in that case, $P_U = V_L$. The provider's decision to reserve at least one first-class unit for Period 2 and offer upgradeable tickets or to reserve no first-class units reduces to the single-unit problem addressed in the basic model. Therefore, Result 1 of the single-unit case applies to the multiple unit case, and

*Result 1** (multiple units): With multiple units of first- and second-class service, a service provider can increase expected profit using upgradeable tickets if the probability of obtaining full price for first class from at least one consumer is greater than

$$\frac{V_L}{V_L + (V_H - V_M)}$$

Result 1* shows that in the multiple-unit case, as in the single-unit case, the provider can increase expected profits by offering upgradeable tickets when first-class units are reserved for sale in Period 2. Furthermore, it is profitable to offer upgradeable tickets under the same conditions in the multiple-units case as in the single-unit case. Result 1* also demonstrates that upgradeable tickets improve profits over and above the improvements achieved by optimizing the number of units reserved for sale in Period 2. Because upgradeable tickets improve profits for all $b > 0$, it follows that, regardless of the optimal allocation determined by yield management, the addition of upgradeable tickets increases the provider's profit.

Interesting questions that arise in the multiple-unit case are how offering upgradeable tickets affects the optimal reservation rule and how many upgradeable tickets to offer.

Let q' denote the probability that more than $b - 1$ Highs will show up in Period 2 and that, therefore, all reserved units will be sold to Highs. The probability that the provider will be able to sell the b th reserved unit is

$$q' = 1 - F(b - 1). \tag{7}$$

Without upgradeable tickets, the provider reserves the b th unit as long as $q' > V_M/V_H$ (see Littlewood 1972).

When upgradeable tickets are offered, the optimal reservation rule and the number of upgradeable tickets offered are as follows (proofs are in the appendix):

Result 3: With upgradeable tickets, it is profitable to reserve the b th unit as long as

$$q' > \frac{V_L}{V_L + (V_H - V_M)}.$$

Therefore, more first-class units should be reserved for sale in Period 2 when upgrades are offered than when they are not.⁸

Result 4: The number of upgradeable tickets offered by the service provider is equal to the number of first-class units reserved for sale in Period 2.

To understand what drives Result 3, assume that $b - 1$ units have already been reserved for sale in Period 2. The provider reserves an additional unit if Highs are willing to pay a sufficiently higher price than are Lows, $V_H > V_M/q'$ (or if the probability to sell an additional reserved unit to Highs is sufficiently high, $q' > V_M/V_H$). Note that when upgradeable tickets are not offered, the provider sells all N_2 units of the second class at V_L regardless of how many first-class units are reserved. Lows are willing to pay higher prices for upgradeable tickets when a larger number of first-class units are reserved because, ceteris paribus, the more units reserved, the more likely Lows are to be upgraded to first class. As a result, the price of an upgradeable ticket, P_U , increases with the number of reserved first-class units. By reserving an additional unit, the provider has the opportunity not only to sell the unit at a higher price in Period 2 but also to increase the price of the upgradeable tickets by ΔP_U . Hence, when upgrades are offered, the provider's expected profit from reserving the b th unit is $q'V_H + N_2^U \Delta P_U$ (where N_2^U is the number of upgradeable tickets sold), which is higher than that in the case of no upgrades, ($q'V_H$). The provider gains more from reserving the b th unit when upgradeable tickets are offered than when they are not offered and thus has a greater incentive to reserve more first-class units.

Another way to look at this is to recognize that upgradeable tickets can be used as a hedge against the uncertainty associated with the arrival of Highs. Selling upgradeable tickets enables the provider to fully use the first-class units even if Highs do not show up, therefore encouraging the provider to reserve more first-class capacity to accommodate the uncertain demand in Period 2.

8. Because of the discrete nature of capacity, there may be some values for which the change in probabilities will not change the number of reserved units.

Given that the optimal number of first-class units is reserved, the service provider offers the same number of upgradeable tickets for sale in Period 1. Increasing the number of upgradeable tickets decreases the probability of being upgraded and therefore also decreases the customers' willingness to pay for upgradeable tickets. When the increase is greater than the number of reserved units, the decrease in revenues due to lower willingness to pay negates the additional revenue from selling more tickets. On the other hand, reducing the number of upgradeable tickets to less than the number of reserved units is not profitable because the revenue from selling additional tickets is larger than the decrease in revenue due to reduced willingness to pay. This occurs because in this case, the probability that an individual customer will be upgraded is not affected too much by changes in the number of upgradeable tickets.

MANAGERIAL IMPLICATIONS AND CONCLUSION

Service providers that offer different service classes (e.g., first class and second class) should find profitable ways to price and allocate supply when facing uncertain demand. Not using first class has higher opportunity costs than not using second class because customers have a greater willingness to pay for first class. Providers typically struggle between two alternative strategies: advance selling first-class units at a reduced price or reserving them for sale at full price. The first strategy eliminates the opportunity to sell first-class units at full price if such demand occurs later, but the second strategy is risky because demand uncertainty may lead to valuable units not being used.

This article suggests that managers introduce upgradeable tickets. As compared to reserving first-class units, employing upgradeable tickets provides a way to ensure that first-class capacity will always be used, allowing the provider to capture more potential value. Compared with advance selling (guaranteed) first-class units at a discounted price, employing upgradeable tickets allows a service provider to sell first-class units at full price whenever feasible. However, because the price needed to induce advance purchases of upgradeable tickets is less than the price needed to induce advance purchases for guaranteed first-class tickets, upgradeable tickets are more profitable only if the probability of selling first-class units for full price is sufficiently high (i.e., the opportunity cost of committing the first-class capacity to advance buyers at a discounted price is high). The upgradeable ticket is similar in some respects to a "put option" for selling the upper class at full price if a full price customer shows up, and having

this option is very valuable when the probability that this customer will show up is high. Hence, upgradeable tickets should be used when the provider is likely to sell first-class units for full price.

Furthermore, compared with the case of no upgradeable tickets, a service provider should reserve more first-class units for sale at full price when upgradeable tickets are offered. This is because upgradeable tickets increase use of first-class capacity, which in turn increases the expected profit of each reserved first-class unit.

Managerial guidelines to improve allocation of upper-class capacity include the following:

1. Use upgradeable tickets to increase profits if the probability of obtaining full price for first class is sufficiently high.
2. When using upgradeable tickets, reserve more first-class units for sale at full price compared to the units reserved without upgradeable tickets.
3. (a) Advance selling is the most profitable policy and reserving is the least profitable if the probability of selling first class at full price is very small.
 - (b) Offering upgradeable tickets is the most profitable policy and reserving is the least profitable if the probability of selling first-class at full price is intermediate.
 - (c) Offering upgradeable tickets is the most profitable policy and advance selling is the least profitable if the probability of selling first-class at full price is sufficiently high.

Upgradeable tickets shift some of the risk from the seller to the buyer, and without analysis, it is not clear whether customers will be willing to accept this uncertainty at a price that is profitable to the seller. Guideline 3 (a) is counterintuitive because upgradeable tickets that are used to salvage first-class capacity seem to be more important when the probability of selling upper-class capacity at full price is low rather than high. However, this research shows that the opposite is true; when this probability is low, it is more profitable to advance sell first-class capacity rather than offer upgradeable tickets. More specifically, Guideline 3 provides a ranking of the relative attractiveness of the three policies for selling first class, namely, advance selling, reserving, and upgradeable tickets.

Some of the features of upgradeable tickets offered by airlines appear to conflict with the conventional view that upgrades are a "cheap" way to reward loyal customers. Specifically, upgrades are offered only to customers that purchased upgradeable tickets. These tickets are more expensive than nonupgradeable tickets, and only a limited number is offered for sale. Our results show that these empirical observations are consistent with optimal behavior. Optimally, upgrades should be restricted to holders of

upgradeable tickets, the provider should charge more for these tickets, and their number should be restricted to the number of first-class seats reserved for full-price customers.

Throughout this article, the assumption has been made that the buyers and seller are risk neutral. Upgradeable tickets can be profitable even if buyers and/or sellers are not risk neutral, but pricing is likely to be different. For example, if customers are risk averse, a seller can profit by lowering the initial price for an upgradeable ticket and adding a surcharge if the upgrade is granted. Alternatively, the seller can raise the initial price for the upgradeable ticket and make refunds or offer other types of compensations to customers if the upgrade is not granted (Biyalogorsky et al., 1999). Both strategies reduce the variance in outcome for the consumer across various possible states and therefore can increase profits when customers are risk averse. Finding the best way to implement such strategies is an interesting topic for future research.

The analysis of upgradeable tickets presented in this article was done within the framework of a single seller. However, market observations suggest that upgradeable tickets proposed in this article also exist under competition. Upgradeable tickets can be a way for airlines to keep their price structure in which business and first-class tickets are priced considerably higher than economy-class fares (10 times higher is not unusual). Under increased competition for high-price customers, instead of decreasing the sky-high fares for upper class, a seller can offer upgradeable tickets at a fare below the full first-class fare (but above the economy fare) and reserve more units for upper class at the full fare (as suggested in Result 3).

Upgradeable tickets can be used to limit price competition in three ways: First, they can be offered only to loyal customers (airlines often offer upgradeable tickets only to frequent travelers or to "elite" status customers). Second, they can be offered only to customers who purchase directly from the service provider at full price (hotels often do not give upgrades to customers who reserve rooms through low-price hotel reservation Internet sites such as www.expedia.com or www.priceline.com). This may encourage some customers to order directly from the provider at a higher "upgradeable price." Third, upgradeable tickets require advance selling. Competition is less intense in the advance period than in the spot period (Shugan and Xie forthcoming). A formal analysis to investigate these and other aspects of using upgrades under competition is an interesting problem that should be pursued in future research.

To conclude, some service companies do not make optimal use of different service classes, leaving it up to frontline employees to decide who gets a free upgrade or

leaving it to customers to decide whether to upgrade themselves (Daspin 2000). In this article, we show that upgrade decisions play an important role in the way service providers manage limited capacity when facing uncertain demand. Service providers can benefit tremendously from upgradeable tickets and improve their allocation decisions by accounting for the effect of upgrades.

APPENDIX

Proof of Result 3

We first derive the reservation rule under upgradeable tickets and then compare it with the reservation rule with no upgradeable tickets. Lows' willingness to pay for upgradeable tickets is $P_U = Pr\{\text{No Upgrade}\}V_L + Pr\{\text{Upgrade}\}V_M$. If b units are reserved,

$$\Pr\{\text{Upgrade}|H = h\} = \frac{b-h}{N_2^U} \Rightarrow \Pr\{\text{Upgrade}\} = \frac{\sum_{h=0}^b p(h) \frac{b-h}{N_2^U}}{\sum_{h=0}^b p(h) \frac{b-h}{N_2^U}} = \frac{1}{N_2^U} \sum_{h=0}^{b-1} p(h)(b-h).$$

The expression for the probability of an upgrade assumes that $N_2^U \geq b$ (i.e., that the number of upgradeable tickets is at least as high as the number of reserved first-class units). In Result 4, we show that this assumption holds, and therefore we can use it in the proof of Result 3.

The price of the upgradeable ticket given b is

$$\begin{aligned} P_U(b) &= \left(1 - \frac{1}{N_2^U} \sum_{h=0}^{b-1} p(h)(b-h)\right)V_L \\ &+ \left(\frac{1}{N_2^U} \sum_{h=0}^{b-1} p(h)(b-h)\right)V_M \\ &= V_L + \left(\frac{1}{N_2^U} \sum_{h=0}^{b-1} p(h)(b-h)\right)(V_M - V_L). \end{aligned}$$

Let q' denote the probability that more than $b - 1$ Highs will appear in Period 2. The expected profits are $E\{\text{Unblocking the } b\text{th unit}\} = V_M$ and $E\{\text{Blocking the } b\text{th unit}\} = q'V_H + N_2^U \Delta P_U$.

Let ΔP_U denote the increase in Lows' willingness to pay for upgradeable tickets due to reserving the b th unit, $\Delta P_U = P_U(b) - P_U(b - 1)$, where

$$\begin{aligned} P_U(b) &= V_L + \left(\frac{1}{N_2^U} \sum_{h=0}^{b-1} p(h)(b-h)\right)(V_M - V_L) \text{ and} \\ P_U(b-1) &= V_L + \left(\frac{1}{N_2^U} \sum_{h=0}^{b-2} p(h)((b-1)-h)\right)(V_M - V_L) \end{aligned}$$

and substituting

$$\begin{aligned}\Delta P_U &= \frac{1}{N_2^U} \left(\sum_{h=0}^{b-2} p(h)[(b-h) - ((b-1)-h)] + p(b-1)(1) \right) (V_M - V_L) \\ &= \frac{1}{N_2^U} \left(\sum_{h=0}^{b-2} p(h)(1) + p(b-1) \right) (V_M - V_L) \\ &= \frac{1}{N_2^U} \left(\sum_{h=0}^{b-1} p(h) \right) (V_M - V_L) = \frac{1}{N_2^U} (1 - q') (V_M - V_L).\end{aligned}$$

Hence, $E\{\text{Blocking the } b\text{th unit}\} = qV_H + N_2^U \Delta P_U = q'V_H + (1 - q')(V_M - V_L) = q'(V_H - V_M + V_L) + V_M - V_L$.

Let $E\{\text{Blocking the } b\text{th unit}\} > E\{\text{Unblocking the } b\text{th unit}\}$. We have

$$q' > \underline{q}_U = \frac{V_L}{V_L + (V_H - V_M)}.$$

We now compare the reservation rule under no upgrades, $q' > \underline{q} = \frac{V_M}{V_H}$, with that under upgradeable tickets, $q' > \underline{q}_U = \frac{V_L}{V_L + (V_H - V_M)}$. Subtracting, we have

$$\underline{q} - \underline{q}_U = \frac{V_M}{V_H} - \frac{V_L}{V_L + (V_H - V_M)} = \frac{V_M(V_L + (V_H - V_M)) - V_L V_H}{V_H(V_L + (V_H - V_M))}.$$

The denominator is positive, so consider the numerator:

$$\begin{aligned}V_M(V_L + (V_H - V_M)) - V_L V_H &= V_L(V_M - V_H) \\ &+ V_M(V_H - V_M) = (V_H - V_M)(V_M - V_L) > 0.\end{aligned}$$

Thus, the threshold probability in the reservation rule is lower when upgradeable tickets are offered. Therefore, introducing upgradeable tickets will never decrease the number of reserved units.

Q.E.D.

Proof of Result 4

Let b^* be the optimal number of reserved first-class units. We first show that profits do not increase if $b^* + 1$ upgradeable tickets are sold.

The profit impact of selling the $b^* + 1$ upgradeable ticket is $P_U(N_2^U = b^* + 1) - V_L - [P_U(N_2^U = b^*) - P_U(N_2^U = b^* + 1)]b^*$. After some algebraic manipulations, it is easy to see from the expression for $P_U(b)$ in the proof of Result 3 that the terms in the equation above cancel each other. The same holds for any other increase in the number of upgradeable tickets above b^* , and therefore the provider has no incentive to sell more upgradeable tickets than the number of reserved first-class units.

Consider now the profit impact of reducing the number of upgradeable tickets to $b^* - 1$: $\Delta \Pi = [P_U(N_2^U = b^* - 1) - P_U(N_2^U = b^*)][b^* - 1] - [P_U(N_2^U = b^*) - V_L]$.

Let a be the probability of an upgrade when $N_2^U = b^*$. The probability of an upgrade when $N_2^U = b^* - 1$ is therefore lower than $a \frac{b^*}{b^* - 1}$ because the reduction in the number of upgradeable

tickets does not increase the probability of upgrade in those instances when no Highs show up in Period 2. We therefore have

$$\begin{aligned}P_U(N_2^U = b^*) &= (1 - a)V_L + aV_M \\ P_U(N_2^U = b^* - 1) &< \left(1 - a \frac{b^*}{b^* - 1}\right)V_L + a \frac{b^*}{b^* - 1}V_M.\end{aligned}$$

Inserting these expressions into $\Delta \Pi$, we get

$$\begin{aligned}\Delta \Pi &< -ab^*V_L + a(b^* - 1)V_L + ab^*V_M - a(b^* - 1)V_M \\ &- [(1 - a)V_L + aV_M - V_L] = a[V_M - V_L] - a[V_M - V_L] = 0.\end{aligned}$$

Therefore, reducing the number of upgradeable tickets to $b^* - 1$ decreases provider profits. The same holds for any other reduction in the number of upgradeable tickets below b^* . Therefore, the optimal number of upgradeable tickets is b^* .

Q.E.D.

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