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The impact of yield management

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Abstract

This article discusses how to increase profits in the hotel industry. In particular, I focus on the way to allocate rooms to distinct types of customers at a different price. A modern approach to do so is to "protect" rooms for premium customers with the so-called yield management, a dynamic pricing approach to adjust allocation among segments, according to the demand. After having discussed this and the other forms of price discrimination, I examine simple heuristics to implement yield management when two or three different segments of customers are present. Finally, I show empirically and theoretically a novel way to determine an appropriate level of overbooking when a proportion of customers systematically deletes the reservation.

Keywords: yield management, pricing, hospitality, segmentation, overbooking.

1. Introduction

In the Internet era being up-to-date with the recent information and changing price and supply accordingly is a key element to optimize. Websites like "Trip Advisor" are drivers of the choices of the customer, so being present on the Internet and considering customers' feedback is more and more relevant.

To take a better decision, the consumer has now several tools, like comparing websites. In this way it is possible to make price comparisons and finally to decide with all the available information. (Kannan and Kopalle, 2004).

The impact of this "new world" is that price search engines reduce the variety of consumers' search costs, keeping only the cost of time spent on the internet looking for information. In addition, it can be found instantaneously the lowest priced e-tailer. (Badinelli, 2000)

The competition, especially for lower level of quality, is now substantially on price because the location is immaterial and the product standardized with manufacturer's warranty.

Even if everything appears to be standardized, dispersion persists in terms of services, shipping costs and other related variables. Price discrimination is a first form of strategy to customize and charging different consumers (segments) different prices. Old concepts of discounts are still holding: discounts for big volumes (quantity) and promotions like coupons, gift certificates, and promotional codes. A recent form of pricing concept is the so-called "versioning" for information goods. To exemplify the concept consider the multiple choice between Windows 7 Professional and Windows 7 Home edition. They are two similar software but the first one is more complete and can be proposed with a higher price. This example illustrates that "versioning" is a new device for price discrimination.

Online reviews are a crucial element to influence through blogs, forums, and reviews. If one obtains a bad review, the firm or the service has generally a very short lifetime. Internet pricing is efficient because menu costs are low, especially for own sites, with changes that are instantaneous. The key element here is information: Look-to-book ratio (airlines/hotels) and clickstream allow the user to monitor and control different packages.

Consumers are now used to price dispersion (A costs 100€ now, 105€ in five minutes) and this created new pricing models like Priceline, Ebay, and auctions. In the past the idea to discriminate prices was very risky: consumers felt treated in an unfair way if they had to pay different prices for the same product.

In this work, after having discussed the relevant issues and opportunities that derive from the Internet market I focus the attention on yield management which is the management of revenues based on a proper allocation of services and products to different types of customers (leisure and business) in different periods of time.

Yield management has significantly altered the industry since its inception in the mid-1980s. It requires advance computing system and analysts with detailed market knowledge. Business leaders use extensively this system (Piga and Bachis, 2006) because they prefer to generate return from revenue growth than to cut on costs and downsizing.

Whereas yield management is specific and involves only perishable inventory, revenue management encompasses a wide range of opportunities to increase revenue. Companies can use these different categories (levels) to improve the existing situation. The levels of revenue management are: pricing, inventory, marketing and distribution channels, combining data mining and operation research with strategy.

In the hotel industry there are several complaints of manager who are dissatisfied to obtain in advance thousands of requests only for popular weekends. The reason is that people are often trying to find a “good deal”, buying into advance while managers would love to protect “hot” days to offer them at higher rates when the deadline comes closer. With this research I intend helping hoteliers to find the benefits to balance current and future demands, according to customer segments. It will be seen that to do so a meticulous records of past bookings is required, and there is the need to know the rules of pricing on the Internet.

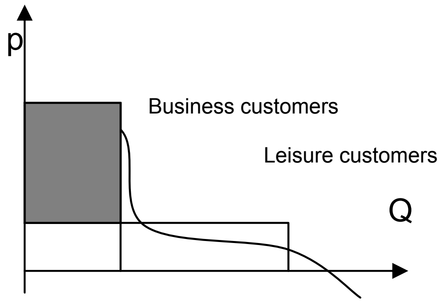
The remainder of the paper is organized as follows: section 2 defines the problem of price discrimination, section 3 explains why yield management can be a solution to maximize revenues (in some cases) In section 4, starting from a real managing problem of an hotel, I propose some heuristics to find the optimal booking limit and I suggest a standard easy model to use to make the choice. In section 5 and 6, I describe extensions of this approach to more complicated cases and how overbooking can be a way to increase revenues systematically. Finally, in section 7 and 8 I discuss the limitations of these approaches and I present the conclusion, clarifying the boundary conditions.

2. The pricing discrimination problem

How should a retailer price? The answer to this question is articulated. Firstly, retailers can price according to items. In this case it can be shown brand name or search by model. Items should be identical across all the retailers. Secondly, and this creates a competitive advantage, the retailer can use differentiators to present different prices (Gallego and Ryzin, 1994). It can be highlighted here that some differentiators are related with the amount of inventory and availability of a product. The more the customer is impatient, the more the product can cost more because it is required to reduce the time to market. The quality of the customer service is another indicator of quality that allows a higher price.

Customers still have different valuations (or willingness to pay) for products. Also, in the Internet market a single price cannot extrapolate all of the value. To exploit the differences between consumers one can use price discrimination, charging different prices to different segments. In this case prices have to be calculated based on value and not on costs. (O’Connor, 2003).

Figure 1. Price discrimination for the two major types of customers



Source: our work

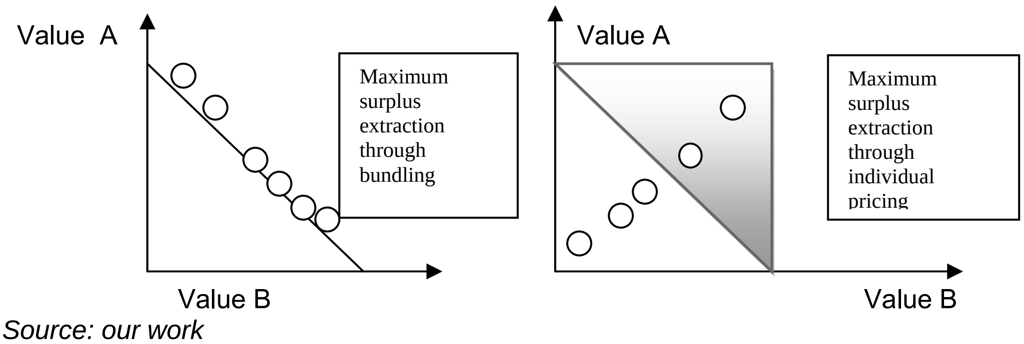
In the figure above it can be seen the advantage for the firm to set different prices, according to the type of consumer: business or leisure. The grey rectangular area represents the incremental margin obtained applying different prices for the business segment. However charging a different cost assuming that a client is business or leisure just by observing him or her is not practicable (1st degree differentiation). It has to be differentiated the product so that clients self-select. Therefore the questions are how to differentiate values, how to select pricing tools and, especially, how to face consumer retaliation in order to avoid resale. A first way to differentiate is a differentiation based on price. In this case you have to consider either exogenous signals, like senior citizen discounts (2nd degree differentiation), or screening, like self-selection by making multiple products at different prices (3rd degree differentiation). A second way to differentiate is based on quantity, like bundling or group pricing. For example, a complete package composed by flight plus hotel can be called dynamic bundling because is a joint product where the price can change across time. Finally, the third way to differentiate is based on the product, which means personalization and product differentiation. The whole argument here is in line with Talluri and Albeniz (2010) who discuss the advantages of dynamic pricing when capacity is fixed, like hotel reservations and airline seats.

2.1 Bundling

If one really likes product A but she doesn't care about product B then putting A and B together has the effect that, to buy A, she will accept paying for B. Bundling is effective if products are negatively correlated.

To better understand why bundling can be so effective in case of negative correlation between products, I present a two-ways graph where I discuss bundling under mixed valuations.

Figure 2a and 2b. The benefits of bundling



Source: our work

In this two-ways graph it can be seen, respectively, the advantages of bundling in the case of substitutes (negative correlation of valuations) and the disadvantages of such an approach in the case of complements (positive correlation of valuations). In particular it can be seen the loss of revenue when bundling complements (the grey triangle in figure 2b).

Apart from profit, bundle pricing can have positive effects in terms of marketing. Bundling allows producing efficiently and with high contribution margins because one can combine products while production or shipping has steep set-up costs. Moreover bundling is used to expand markets, it stimulates volumes, offering higher priced individual items to unusual customer segments. Bundling is also used to improve performances, recognizing that certain components perform better together than separately and finally it cements loyalty, letting consumers understand a full range of product and service benefits.

3. When supply differs from demand

The daily control of sales is an operational problem used to increase revenues and transactions.

Revenue management is a prevision of consumer behavior to optimize prize and quantity to maximize revenues Yield management is the inventory-focused branch of revenue management (Talluri and Ryzin, 2004).

There are three different levels of yield management: a strategic one, where the goal is to segment the market and to identify prices accordingly, a tactical one, where are calculated and updated booking limits for each segment, and an operative one, where there is the final choice for each reservation.

In this part, the focus is on tactical decisions rather than strategic ones to study services where the use of dynamic quantities and dynamic pricing can increase profits.

All the industries that are discussed have one or more of the following attributes: impossibility to increase supply in the short term (fixed capacity), variable demand by seasons and day of week, competition and economic conditions.

The approach used to optimize revenues is to forecast using our historical data and to apply optimization results to the next inventory and price decisions.

3.1 Yield Management

The term *yield management* is used in many service industries to describe techniques to allocate limited resources, such as airplane seats or hotel rooms. In this part it is presented how this technique can be used to allocate limited resources in the hotel industry. Yield management also allows differentiating between varieties of customers, such as business or leisure travelers. By adjusting the allocation, a firm can optimize the total revenue or "yield". Considering that these techniques are used by firms with perishable goods (such as yogurt), or by firms with services that cannot be stored at all (such as airplane seats), these concepts are often called perishable asset management (O'Conor, 2003).

The impact of yield management in terms of revenue increase in some industries is huge. Yield management for example has been an enormously important innovation in the service industries (Netessine, Shumsky, 2002). The advantage of this technique is to keep the old capacity but determining how much inventory to sell to the "upfront" market and how much to reserve and perhaps to sell later at a higher price to the "premium segment". Manufacturing capacity is as perishable as an airline seat. If you miss it, the opportunity to use the capacity is gone forever (Yelkur and Da Costa, 2001).

This part tries to replay to this question: how can a manager allocate perishable inventory among a variety of customer segments? Consider a hotel with 300 rooms[1] used by both business and leisure travelers. The hotel must decide whether to sell rooms well in advance at a relatively low price (i.e. to leisure travelers), or to "keep the rooms", waiting for a sale at a higher price to late-booking business travelers. There can be variations of the problem. For example, it might be changed the booking limit up or down as time passes or some rooms can be classified as more flexible, like economy and deluxe rooms.

There are several reasons that justify the use of yield management in particular markets. Firstly, it is expensive or impossible to store excess resource. If there is an available room tonight it cannot be stored for the customer of tomorrow. Secondly, before it is known how many business customers will arrive, there is the need to "protect" a number of rooms for them, considering that each segment has a different demand curve. In order to identify business customers

[1] We are assuming that all rooms are identical, but they can vary in size and amenities.

purchase restrictions and refund ability requirements can be used. Business customers are more indifferent to the price and they tend to pay more if there more flexibility. The great advantage is that the same unit of capacity, our rooms, can be used to deliver different product and services to differentiate something that is indifferent (rooms are the same service, whether used by business or leisure travelers). Finally, holding rooms for future profit is not illegal or irresponsible. Therefore hoteliers, except in emergency cases, have broad freedom of actions (Tso and Law, 2005).

Our main concern here is to introduce booking rules that create barriers between market segments. For instance, leisure travelers are keener to receive a discounted room on Monday, because they don't prefer to go home on weekend. The goal of our problem will be to sell as many rooms to business customers at a higher price as possible while keeping room utilization high.

4. Heuristics to optimize, protecting the premium level

Suppose that our hotel has 300 rooms available for April 27. Let's also assume that April 27 is a Tuesday. It is now the end of March and the goal is to try to sell out all 300 rooms to leisure travelers at a discounted price, but we also know that an increasing number of business customers will request rooms as April 27 approaches and that these business customers are willing to pay full price. Therefore we must decide how many rooms we are willing to sell at the leisure segment, meaning how many rooms we protect for the full price payers. If too many rooms are protected, then there is the risk to remain with empty rooms when April 27 arrives. If too few are protected, then the hotel loses the extra revenue it may have received from business customers[2].

It has to be identified the maximum number of rooms that may be sold at the discount price. The assumption that I will partially keep in the empirical part is that leisure customers arrive *before* business customers so the *optimal limit* constraints the number of rooms that these customers get.

This assumption is reasonable and coherent with the literature on advance purchase discounts which predicts that leisure customers are generally booking earlier than business customers to pay less (Gurion, 1996; Su, 2007; Abrate et al., 2012). After that the optimal limit is reached, all future customers will be offered the full price for that date. The *premium level* is the number of

[2] This section is as an adapted solution (the real data are not presented here because of disclosure policies of the chain) to a real problem of room allocation in the hospitality industry. I thank Franchin Luciana, manager of Hotel Europe Aosta (Italy), who shared with me her thoughts on price discrimination and explained me their need to have a clear and simple rule to allocate rooms.

rooms we will *not* sell to leisure customers because of the possibility that business customers might book later in time.

Since in the example given there are 300 rooms available in the hotel, and just two fare classes for simplicity, the *optimal limit* is given by 300 minus the premium level.

The hotel's task is to identify either an optimal limit or a premium level, since knowing one allows determining the other. Suppose the hotel considers protection level 'X' instead of current premium level 'X+1' (X might be anything from 0 to 299). Once that 300-X-1 rooms have already been sold a prospective customer calls and wishes to reserve the first "protected" room at the discount price.

Should the hotelier lower the protection level from X+1 to X allowing the booking of the $(X+1)^{th}$ room at the discounted price? Or should it refuse the booking to gamble that it will be able to sell the same room to a full price customer in the future? The answer depends on (i) the relative sizes of rooms to keep at full price (level of X) and (ii) the anticipated historical demand for full price rooms.

A similar kind of problem is discussed in Netessine and Shumsky (2002). I present a graphical approach to exactly figure out the optimal limit and I extend the discussion to some more complicated case where three different segments are present.

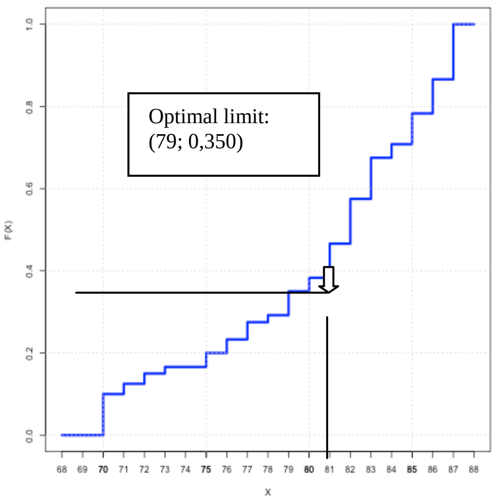
Suppose that the discount price is €100 per night while the full price is €150 per night. The anticipated demand for rooms at full price has to be presented (D). This distribution can be obtained from historical demand. Let's assume that there is the distribution from 120 days of historical demand.

In table 1 I present a hypothetical distribution of historical demand. The first column represents the historical demand for rooms at the full rate. In the second column I present the number of days where such a demand was present (i.e. in the last 120 days it happened 5 days that the demand of rooms at the full price required was exactly 77). Particularly useful in the table is the column "Cumulative Probability" which represents the fraction of days with demand at or below the number of rooms in the first column (X). The number is computed as the cumulative relative frequency distribution. If we decide to protect the $(X+1)^{th}$ room from sale, then the room may, or may not, be sold later. It will be sold only if demand D at full fare is greater than or equal to X+1, and this event has probability 1-F(X). For example if the $(X+1)^{th}$ room is the room 78^{th} room there is a probability of 1-0,292 that this room will be sold at a full price. Likewise, the protected room will not be sold if demand is less than or equal to X, with probability F(X). In our previous case, the probability not to sell the room at a full price is equal to 0,292, which means a 29,2% to earn zero[3].

One can decide to play safe, lowering the protection level from X+1 to X which guarantees revenue of €100. Protecting X+1 rooms has an expected value for the $(X+1)^{th}$ room equal to: (1-F(X))(€150)+F(X)(€0)=(1-F(X))(€150)

[3] We are assuming that it is very difficult to re-allocate a protected room at a lower price as last-minute.

Table 1. Historical demand for rooms at the full fare and empirical distribution function



Source: our work

Demand for rooms at full fare (X)	# Days with Demand	Cumulative Probability F (X)= Prob (D≤X)
0-70	12	0,100
71	3	0,125
72	3	0,150
73	2	0,166
74	0	0,166
75	4	0,200
76	4	0,233
77	5	0,275
78	2	0,292
79	7	0,350
80	4	0,383
81	10	0,466
82	13	0,575
83	12	0,675
84	4	0,708
85	9	0,783
86	10	0,866
>86	16	1,000
Total	120	1,000

Therefore we lower the protection level to Q as long as: (1-F(X))(€150)<=€100
The F(X) can be derived.
F(X) = (€150-€100)/€150 = 0,333. The result is intuitively reasonable. If the premium room costs €150 and the other €100 then with 2 rooms at premium price the hotelier earns the same amount as with 3 rooms at discounted price.

Now, F(X) is the third column in Table 1. It can be simply scanned the table from the top of the table towards the bottom until it is founded the smallest Q with a cumulative value greater than or equal to 0,333[4]. The answer here is that the optimal protection level is X^*=79 with a cumulative value of 0,350. It can be now evaluated the booking limit: 300 – 79 = 231. On one hand, if it is chosen a larger X^*, then we would leave unsold too many rooms on average. On the other hand, if X^* is set at a smaller value, we are likely to sell too many rooms at a discount. In this way too many business customers are turned away (on average).

In the example we had two fare classes: r_H the higher price €150, while r_L is the lower price, €100. We had a random variable D, representing the distribution of demand at the high fare. Since there are just two fare classes, the optimal booking limit for low far class is equal to the total capacity minus X^*.

[4] Note that we could apply this reasoning also with a continuous distribution instead of a discrete one.

Formally, the standard formula to be used is the following:

$$F(Q^*) \geq \frac{r_h - r_l}{r_l} \quad [1]$$

where r_h is the highest price and r_l is the lowest one.

5. More complex cases

Suppose now, and this is a more realistic case, that we have three segments, business price (BP), full leisure price (FLP) and discounted leisure price (DLP). The prices to the different segments are €560, €450 and €360, respectively. We have also previous forecasts: rooms required with BP are distributed like a Normal (17; 3.7), FLP ~ Normal (110;40) and DLP ~ Normal (122; 3.6). To solve this problem we have to calculate how many rooms to protect for BP+FLP against DLP. For this reason we can calculate the weighted price

$$P_{BS+FLP} = \sum_{i=1}^{n=2} p_i n_i \quad [2]$$

Plugging our empirical data we obtain: $\frac{560*17+450*110}{127}$ = 464. Now, we have to derive the normal distribution of the combined demand which is ~ Normal (127, 40.2) where 40.2 is obtained as the square root of the sum of the two original standard deviations squared. Now we have all the data to calculate how many rooms to "protect" for BP and FLP. This is a continuous case therefore we derive the quantile of the normal distribution (360/464) and then we compute the result in the formula to calculate the appropriate number of rooms to protect $X_i = \overline{X} \pm z\sigma$ → 127-0.775*40.2=96.0. This is the number of rooms that, in this case, we have to protect for BP and FLP against DLP. Now, to separate the first two segments (BP and FLP) we work iteratively. To calculate how many rooms to protect for BP is pretty easy now because we don't have to derive another joint distribution as we simply calculate the inverse normal (450/560) which are the two prices for BP and FLP, respectively, and we can obtain the number of rooms to reserve for BP: $X_i = \overline{X} \pm z\sigma$ → 17.0-0.80357*3.7=14.0. Having said that, we are ready to identify all our nested booking limits: 14 for BP, the difference between 96.0 and 14.0 equal to 82.0 for FLP and the remaining units for the leisure discounted segment (DLP).

6. The opportunity to overbook

The fact that a customer may not appear creates the opportunity to use overbooking. It is in fact possible for a customer to reserve a room in a hotel and not show up for the departure. In this case the hotel suffers of an empty room resulting in lost revenue for the hotelier. In order to account this phenomenon, based on historical rate of no-shows, the company allows booking more rooms than available ones. Being the arrival of customers randomly distributed with a certain standard deviation and mean, it can happen that a larger than expected proportion of customers show up, then the company will be forced to find another hotel for these people plus, in some cases, paying some penalties. Airlines, restaurants, rental car agencies overbook (Weatherford and Bodily, 1992).

The optimal overbooking level considers (i) lost revenue deriving from empty rooms, (ii) financial compensation to transferred customers, and (iii) loss of customer goodwill (they can decide not to use the service anymore) when the firm is faced with more demand than capacity. In particular in the hotel industry sometimes is not easy to find an appropriate alternative for the client. Imagine a four-star hotel during the Christmas period in a popular city for holidays. It can be extremely difficult to offer the same or higher service for the client in another hotel because there can be a scarce number of hotels of such a quality or simply because, if they are present, they don't have available rooms.

In this case I present before the problem theoretically, showing that the method is very similar to the one used for yield management.

Theoretically the problem of overbooking can be presented as follows: Let Q be the number of rooms that can be overbooked. Let Z be the number of no-shows with distribution F(z). I define the underage penalty by U and the overage penalty by O in the case a client has to be refused. U represents the opportunity cost of having an available unsold room.

If Z>Q then Z-Q more rooms could have been sold (missing U multiplied for the number of unsold rooms). If Z<Q then there is the need to transfer Q-Z customers at the cost O. As I described empirically, the formula for the optimal number of overbooking can be derived as:

$$F(Q^*) \geq \frac{U}{U+O} \qquad [3]$$

Suppose that our cited establishment of 300 rooms estimates that the number of people who book a room but fail to show up on the night in question is distributed normally with mean 20 and standard deviation 10. Our hotel estimates that it costs €400 to transfer a customer (cost of alternative accommodation plus a possible voucher for a future stay at our hotel in the future). On the opposite, if a room is not sold then the hotel loses the revenues equal to one night at a price that may vary between business and leisure fare[5].

How many bookings should our hotel allow?

First an average fare per night has to be calculated. If generally one fifth of our clients are business and the remaining part leisure it can be computed the value as follows: (1/5)*150+(4/5)*100=110

Where 150 and 100 are the business and leisure fares, respectively.

The critical ratio is calculated as 110/510: at the numerator there is the benefit for placing the room (110) divided by the overall risk in case of overbooking (paying 400 to transfer and the incremental 110 with respect not to overbook rooms).

From the Normal distribution table it is obtained φ (-0,57)=0,2157. From the optimal z* it can be calculated the optimal number of rooms to overbook which is Q*=20-0,57*10=14,3

This means that in our case up to 300 (the total number of rooms of the hotel) + 14 = 314 bookings should be allow optimally.

It is worth mentioning here that the value O may increase as the number of 'extra' customer's increases. It is in fact reasonable to think that at some point the agency's extra supply will run out, resulting in a greater cost.

7. Limitations and extensions

There is a variety of problems and possible extensions when implementing a yield management system. In this session I discuss the main complications and how to solve them theoretically. I recognize also some limitations in using the heuristics presented.

Using historical demand to predict future demand is not always possible. There can be censored data, meaning that the firm does not record demand from clients who were denied a reservation. Sometimes it would be interesting to measure a variety of predictable events like seasonality, day of the week, special events, and most recent demand patterns which are a driver of customer preferences.

A limitation of our approach is that hoteliers could also use dynamic booking limits, changing booking limits over time in response to the latest demand information. If it is assumed for example that the number of business customers will be higher than the effective one when few days are remaining it can be raised the number of discounted rooms for leisure travelers.

Another assumption that I made was that the proportion of leisure customers who are shut out from discount rooms decides to look for other hotels or simply to avoid booking a room in our hotel. In reality some leisure clients may attempt to book a room at the full price.

[5] Consider also that often hotels charge a penalty for late cancellations (within 24 hours).

Even if customers are in the same fare class, this doesn't mean that they are all equal. If guest A wants to occupy the room for one week while guest B wants to occupy the room only for a particular night's stay, then not selling the room to guest A means that revenues for more days will be lost (are hoteliers able to re-allocate the room at least for some other nights?). In airline industry when code-sharing partners are involved there are additional complications because each of the partners has an incentive to consider the other partners' policy.

Finally an extension, which is also a complication, is how to consider group booking request at a discount rate. Accepting or denying these offers is a more risky decision because it involves more rooms and, subsequently, a potential higher loss.

8. Conclusion

Hotels use yield management to maximize the return. Having the right market mix means selling rooms and services at the right time, at the right price, and to the right people.

Monitoring historical demand and optimization are core elements of yield and operation management. In particular, the goal here is to create adequate fences between consumers. One way to do so is making use of price elasticity to segment the market. Here segments are competing for the same inventory. In capacity-constrained cases, the seller rejects lower revenue generating customers in the hopes that the inventory can be sold to a higher valued segment. It is a risk that requires an estimate of the marginal revenue curve of the high-value and the low-value segment, finding where the marginal revenue of the high-value segment crosses the actual value of the low-value segment. In this way I decide how many reservations should be protected for the high-value segment.

Technically, the equilibrium is the point where the number of units of inventory for the higher valued segment is equal to the inverse probability of demand of the revenue ratio of the lower valued segment to the higher valued segment. Nevertheless, these are heuristics and only with the implementations of replications, such as Monte Carlo simulation, it is possible to find optimal protection levels.

Yield management systems increase revenues significantly more than relying on pure personal judgments when making pricing decisions, which can lead to irrationality (Peterson, 2005). Several articles show that with yield management revenues can be increased significantly (Sanjay, 2009; Ingold et al., 2000). In fact, without a model to follow people tend to price too high when they have high levels of inventory and too low when their inventory levels are low.

We discussed the importance of the internet to implement yield management. One way to find different segments is time based discrimination on the internet, a special case of price discrimination in which producers charge different rates for a given good or service depending on the time, day, month, and so on. Changing prices on the internet is efficient and nowadays people do not perceive paying a different price for the same product to be unfair. For instance, it is common practice in the hospitality industry to change prices moving toward a certain booking date, considering also seasons and special events. Another example of this pricing strategy is found in airline sectors, which may charge higher prices when the reservation and the actual departure of the booked flight are pretty closed.

On one side dynamic pricing allows online companies to segment and to adjust the prices to correspond to an exact customer's willingness to pay. On the other side, customers can prevent firm's strategies, anticipating changes. The equilibrium is the point where value delivery equals value extraction.

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