Simulating Overbooking in YM

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Abstract-

In industries where yield management is used, one of the major problems in maximizing revenue is the cancellations and no-shows of consumers. To avoid such type of problems, the firms sometimes use overbooking. This paper is an attempt to design simulator for overbooking in airlines. Two models for overbooking are presented, one with fixed overbooking and other with random overbooking. In fixed overbooking model, overbooking is estimated through predetermined cancellations. While in random overbooking, overbooking is estimated randomly. The results obtained are as per expectations.

Keywords - Cancellations, Genetic Algorithm, No-shows, Overbooking, Yield Management

I. Introduction

The field of airline revenue management studies maximization of revenues obtained by selling airline seats. An important problem of this field requires the development of a revenue-optimal strategy of customer selection. The product in airlines is said to have a perishable nature because its value becomes zero if it not sold by the end of booking horizon, which begins when the flight is opened for sale and ends when the flight takes off.

Typically there are significant differences in the preferences of customers of an airline company. Some customers, usually business travellers, demand flexibility in cancellation options and return tickets, while those travelling for leisure do not have these restrictions and opt for cheaper non-refundable tickets. Therefore, airline companies generally offer seats at different fares to utilize differences in passenger's expectations to their own advantage. The number of business travellers is quite small in proportion, and business tickets are booked at the last minute, thereby making it important for the company to retain a few seats until the end of the booking horizon. The question that then arises is: how many seats should be allowed to be sold at a low fare? If one reserve too many seats for high-revenue passengers, it is possible that the plane will fly with many empty seats; on the other hand if all the seats are sold at discounted rates, one will potentially lose high-revenue passenger. Thus an important task is to determine the upper limit, called the booking limit, on the number of seats to be sold at or allocated to each fare offered. The above described problem is complicated by uncertainties in the customer behaviour and forecasts. Forecasts are generally prepared to estimate the probability distribution of the number of arrivals in each fare class. Inevitably some passengers cancel tickets. Hence airlines overbook planes in order to minimize the probability of flying with empty seats, which adds to the complexity of the problem because cancellations are random. Thus seat allocations should account for random cancellations and the feature of overbooking. Some realistic features of actual airlines system include: (i) random customer arrivals for booking (ii) random cancellations (iii) change in arrival rates with time, etc., i.e., arrival do not follow any particular order. Overbooking may be defined as a strategy whereby service providers accept and confirm more reservations than the capacity they allocate for providing the service. Thus, the overbooking strategy may result in service denial to some consumers if the number of actual show-ups at the time of service exceeds the allocated capacity. A question one may want to ask is whether consumers can benefit from overbooking. A quick answer to this question would be that overbooking enables more consumers to make reservations. Overbooking is widely observed in the airline industry. In fact, most readers would recognize the following statement, which is printed on most ordinary airline tickets.

"Airline flights may be overbooked, and there is a slight chance that a seat will not be available on a flight for which a person has a confirmed reservation. If the flight is overbooked, no one will be denied a seat until airline personnel first ask for volunteers willing to give up their reservation in exchange for a payment of the airline's choosing. If there are not enough volunteers, the airline will deny boarding to other persons in accordance with its particular boarding priority. With few exceptions, persons denied boarding involuntarily are entitled to compensation. The complete rules for the payment of compensation and each airline's boarding priorities are available at all airport ticket counters and boarding locations."

In the airline industry, passengers with confirmed reservations who are denied boarding must be offered the choice of a full refund for the ticket or an alternative flight to continue their journey. In this paper, two models are presented to handle overbooking. First model considers that the overbooking is done in the fixed amount in each fare class, while the cancellations are random. Second model considers the random overbooking along with random cancellations. The optimal allocations are done by using GA as in [1]. The fixed overbooking is calculated by using cancellations evaluated as in [2].

II. LITERATURE REVIEW

Gosavi[3] developed a model-free simulation based optimization model to solve a seat-allocation problem arising in airlines. The model is designed to accommodate a number of realistic assumptions for real-world airline systems, in particular, allowing cancellations of tickets by passengers and overbooking of planes by carriers.

Overbooking is used by the airline companies to protect themselves against vacant seats due to no-shows and late cancellations. On the other hand, it may also happen that some of the reservations are denied boarding due to the lack of capacity at the departure time. In such a case, the airline faces penalties like monetary compensations, and even worse, suffers from bad public relations. Even though the overbooking decision involves uncertainties regarding the no-shows and cancellations, accepting more booking requests than the available capacity is still a commonly-used, profitable strategy because the revenue collected by overbooking usually exceeds the penalties for denied boarding [4]. Overbooking can also cause problems if everyone who had made a reservation comes. Mostly in such a situation like this, there are also standard policies, one of them is that the passengers will be served by others or given compensations [5]. In addition, employees have to be trained in how to handle in situations of overbooking because, both customer and employee satisfaction may suffer. Finally, this means that companies selling perishable products carry a high revenue risk. Revenue Management can be used as a technique to reduce this risk by creating a certainty about the demand for those products and by using overbooking policies. The overbooking limit, which is also referred to as virtual capacity or total booking limit, is the maximum number of booking requests an airline company is willing to accept. An allocation policy specifies how to allocate this virtual capacity to each fare class. Although a common practice is first setting the virtual capacity and then doing the allocations [6], this heuristic approach in fact undermines the effects of these two decisions on each other. Therefore, it is natural to study the joint capacity allocation and overbooking problem which is, in general, difficult to solve largely because of the uncertainty in the class dependent no-show and cancellation parameters. Overbooking means that more products are reserved than there is capacity. Thereby it is essential that companies develop an overbooking policy, to develop this, a firm must have more information about the number of no-show passengers and cancellations on a flight over time. Overselling means that customers who pay the high price are reserved despite of the capacity and customers who pay a low price are advised to take an alternative product [7]. The alternative could be depart of another airport or depart one day before or one day later.

Lan et al. [8] formulated a joint overbooking and seat allocation model, where both the random demand and no-shows are characterized using interval uncertainty. They focus on the seller's regret in not being able to find the optimal policy due to the lack of information. The regret of the seller is quantified by comparing the net revenues associated with the policy obtained before observing the actual demand and the optimal policy obtained under perfect information. The model aims to find a policy which minimizes the maximum relative regret.

Chatwin [9] examined a continuous-time single fare class overbooking problem, where fares and refunds vary over time according to piecewise constant functions. In his model the arrival process of requests is assumed to be a homogeneous Poisson process, and the probabilities to identify the type of a request are independent of time. He assumes that the reservations cancel independently according to an exponential distribution with a common rate, and the arrival process of requests depends on the number of reservations. Under these assumptions, the author formulates the problem as a homogeneous birth-and-death process and shows that a piecewise constant overbooking limit policy is optimal. A closely related study is given by Feng et al. [10]. They considered a continuous-time model with cancellations and no-shows. They derived a threshold type optimal control policy, which simply states that a request should be admitted only if the corresponding fare is above the expected marginal seat revenue (EMSR). Karaesmen and van Ryzin [11] examined the overbooking problem differently. Their model permits that fare classes can substitute for one another. They formulated the overbooking model as a two-period optimization problem. In the first period the reservations are made by using only the probabilistic information of cancellations. In the second period, after observing the cancellations and no-shows, all the remaining customers are either assigned to a reserved seat or denied by considering the substitution options. They give the structural properties of the overall optimization problem, which turns out to be highly nonlinear. Therefore, they propose to apply a simulation based optimization method using stochastic gradients to solve the problem.

III. PROBLEM DEFINITION AND FORMULATION

In this problem an assumption regarding a flight operating between a specified origin and destination has been made. The reservation for the flight starts form the first date of expected reservation up to the date of departure. Another assumption is to fix the fare of each class and also assumed as known.

The number of customers travelling in each class should be greater than or equal to lower bound and less than or equal to the upper bound.

On the basis of above assumptions, the objective function can be written as:

Max. $\Sigma_{\beta} \Sigma_{\alpha} N_{\alpha, \beta} F_{\beta}$ ……………………………………………………………………(1)

Subject to the constraints

$\Sigma_\beta \Sigma_\alpha N_{\alpha,\beta} <= C_t$ & $L_{\alpha,\beta} <= N_{\alpha,\beta} <= U_{\alpha,\beta}$ for all α and β,
$N_{\alpha,\beta} >= 0$,
Where C_t = Total capacity of a flight
$N_{\alpha,\beta}$ = Number of customers belonging to class β during time slice α.
F_β = Fare for class β.
$U_{\alpha,\beta}$ = Upper limit of demand for class β during time slice α.
$L_{\alpha,\beta}$ = Lower limit of demand for class β during time slice α.

Let X be the number of no-shows and suppose the forecast for distribution of no-shows be the binomial distribution function F(*x*). Let Y be the number of seats that will be overbooked, i.e., if the airplane has *S* seats then the tickets will be sold upto *S+Y* tickets. Let the underage penalty be defined by *B* and the overage penalty by *C*. In this case C represents the net penalties that are associated with refusing a seat to a passenger holding a confirmed reservation. Here, *B* represents the opportunity cost of flying an empty seat. To explain further, if *X>Y* then the number of seats that could have been sold more are *X-Y* and those passengers would have seats on the plane. So B equals the price of a ticket. If *X<Y* then the customer that needs to be bumped are *Y-X* and each has a net cost of *C*. Thus, the formula for optimal number overbooked seats takes following form: is smallest value Y* such that

$$F(Y^*) \geq \frac{B}{B+C}$$

In simple words the number of seats that should be overbooked are the smallest possible value for F(Y*).

Therefore, the final objective function taken the following form:

Max. $(\Sigma_\beta \Sigma_\alpha N_{\alpha,\beta} F_\beta - C_{pen})$ ……………………………………………………………………..(2)

Subject to the constraints
$\Sigma_\beta \Sigma_\alpha N_{\alpha,\beta} <= C_t$ & $L_{\alpha,\beta} <= N_{\alpha,\beta} <= U_{\alpha,\beta}$ for all α and β,
$N_{\alpha,\beta} >= 0$, $C_{pen} >= 0$.
Where C_{pen} = Penalty for bumping a customer.

IV. Implementation using Genetic Algorithm

On the basis of the simulator presented in [2], the cancellations are estimated in each fare class. These estimations are used to overbook the number of seats in each category using the simulator shown below:

Simulator using GA for Fixed Overbooking

1. Fc = No_of_classes
2. U_b = Upper_Bound_in_each_class
3. For I = 1 to Fc
4. $U_b = U_b$ + Prob_can[I] // Prob_can[I] is calculated through the simulator for cancellation
5. Init_pop = Randomly Generated population.
6. curr_pop = Init_pop.
7. While (!termination_criterion)
8. Evaluate Fitness of curr_pop using fitness function.
9. Select mating pool according to Roulette-wheel Selection OR Tournament Selection.
10. Apply Crossovers like One-point, Two-point & Uniform Crossovers on mating pool with probability 0.80.
11. Apply Mutation on mating pool with probability 0.03.
12. Replace generation with $(\lambda + \mu)$-update as curr_pop.
13. End While
14. Display Revenue with and without overbooking.
15. End

This simulator works in combination with the earlier simulator. In this simulator the overbooking capacity is fixed on the basis of cancelled estimations using the previous simulator.

Simulator using GA for Random Overbooking

1. Fc = No_of_classes
2. U_b = Upper_Bound_in_each_class
3. ξ = Survival Probablity
4. For I = 1 to Fc
5. Prob_can[I] = Random Number between 0 and 1- ξ
6. $U_b = U_b$ + Prob_can[I]* U_b
7. Init_pop = Randomly Generated population.
8. curr_pop = Init_pop.
9. While (!termination_criterion)
10. Evaluate Fitness of curr_pop using fitness function.
11. Select mating pool according to Roulette-wheel Selection OR Tournament Selection.
12. Apply Crossovers like One-point, Two-point & Uniform Crossovers on mating pool with probability 0.80.

13. Apply Mutation on mating pool with probability 0.03.
14. Replace generation with (λ + μ)-update as curr_pop.
15. End While
16. Display Revenue with and without overbooking.
17. End

This simulator is based on random overbooking.

V. Results

In this case, a single flight is considered to operate between given origin and destination. The capacity of the flight is assumed to be 100.

Genetic algorithm is used as a solution technique using various combinations of different operators. The following GA parameters are taken into considerations:
Population size = 75
Maximum number of iterations = 100
Cross-over probability = 0.90
Mutation probability = 0.03
Tournament Selection parameter = 0.75
Number of simulations = 100

Using the above parameters and various combinations one can get the table 1 for the optimum results without cancellation, which is shown below as already explained in [1].

TABLE1
Lower, Upper and Best Estimated Demands in Each Assumed Fare Class

		Demand		
Fare Class	**Far e**	**Lower Limit**	**Upper Limit**	**Best Estimation**
1	100	0	63	30
2	250	30	45	45
3	500	13	20	20
4	800	2	5	5

For estimating cancellations, the simulator presented in [2] produces the results as shown in table 2.

TABLE 2
Probability of Cancellation in each Fare Class

Fare Class	Average % Probability of Cancellation	Standard Deviation	Range of Probability
4	10.9	6.69	4.21 - 17.59
3	18.8	8.39	10.41 - 27.19
2	17.9	6.81	11.09 - 24.71
1	16.7	8.06	8.64 - 24.75

After estimating the cancellations, the simulator for overbooking with fixed estimation as calculated through above explained simulator is executed and the results obtained are shown in table 3. The revenue comparison with and without overbooking is done in fig.1.

TABLE 3
Comparison of Revenue without Overbooking and with Fixed Overbooking

Fare Class	Fare	Avg. No. of Seats Cancelled	Revenue after cancellation and without overbooking	No. of Seats Overbooked	Revenue after cancellation and with overbooking	Profit/Loss due to Overbooking
1	100	10.8 ≈ 11	1900	5	2400	800
2	250	8.9 ≈ 9	9000	8	11000	2000
3	500	4.8 ≈ 5	7500	4	9500	1875
4	800	1	3200	1	4000	0
Total		26	21600	18	26900	4675

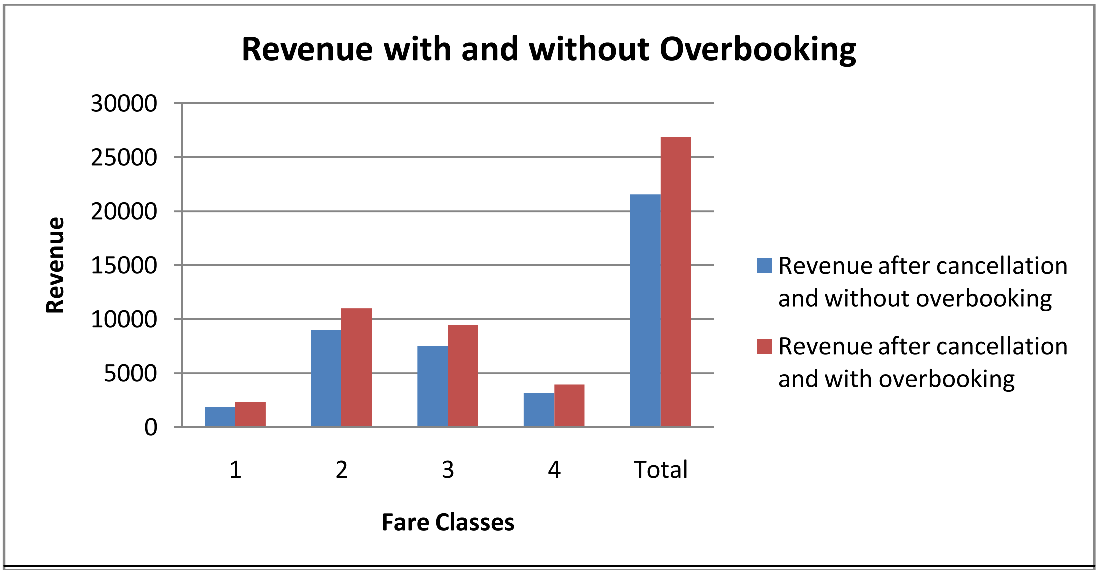

Fig.1 Comparison of Revenue after cancellation (with and without fixed overbooking)

The last simulator is using random overbooking instead of fixed overbooking. The results obtained are shown in table 4. The fig.2 shows the comparison of revenue with and without random overbooking.

TABLE 4
COMPARISON OF REVENUE WITHOUT OVERBOOKING AND WITH RANDOM OVERBOOKING

Fare Class	Fare	Avg. No. of Seats Cancelled	Revenue after cancellation and without overbooking	No. of Seats Overbooked	Revenue after cancellation and with overbooking	Profit/Loss due to Overbooking
1	100	$2.6 \approx 3$	2700	3	3000	300
2	250	$1.4 \approx 1$	11000	$1.7 \approx 2$	11050	50
3	500	$1.4 \approx 1$	9500	$1.2 \approx 1$	10000	1500
4	800	$0.1 \approx 0$	4000	$0.2 \approx 0$	4000	0
Total			26950		28250	1850

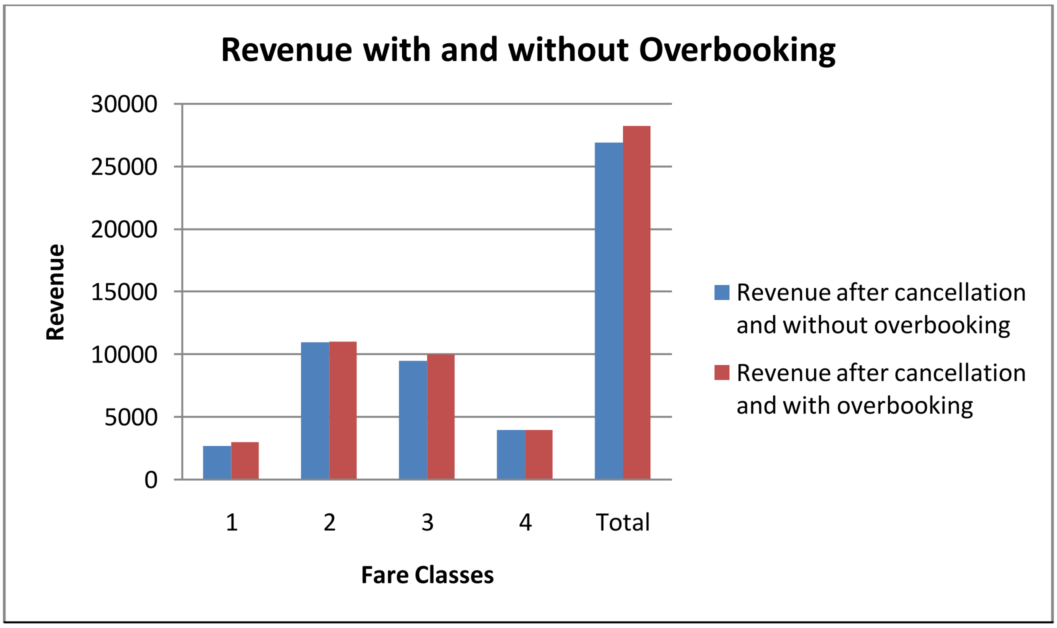

Fig.2Comparison of Revenue after cancellation (with and without random overbooking)

In the last of the results the comparison between the profits obtained via both the schemes is drawn. The comparison is shown below in fig. 3.

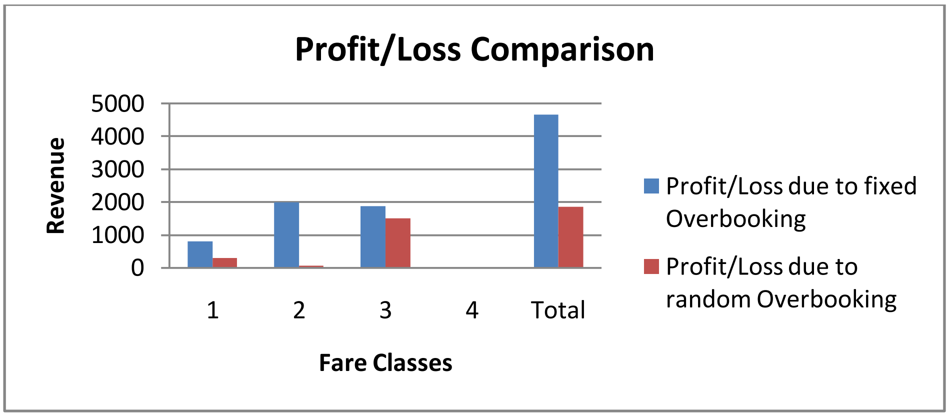

Fig.3 Profit/Loss Comparison of fixed and random overbooking

VI. Interpretation

The purpose of this paper is to predict the overbooking in airline YM. The two models have been formulated using fixed overbooking scheme and random overbooking scheme. In the fixed overbooking scheme, it has been assumed that the numbers of cancellation are known. The cancellations are calculated through binomial distribution as this distribution tells the probability of showing-up a customer in an efficient manner. In the second model the random overbooking concept is considered. The number of overbooking is not fixed and changing randomly. In both the models a penalty function is taken into consideration i.e. is a customer is bumped by the airline, it need to given compensation to the customer. The performance of both the models is explained below:

Looking at table 3 and fig. 2, which is based on first model, it is clear that if no overbooking is done, a lot of revenue may be lost. Although even after overbooking the revenue loss may still occur, but they are much less as compared to no overbooking method. In some cases the penalty needs to be paid by the airlines to the customer, if number of customers that arrive exceeds the number of seats and some customer are bumped. This may result in more loss of revenue not only in present case but also in future due to loss of goodwill. However, taking into all considerations the overbooking is still a good criterion to avoid loss of revenue due to cancellations and no-shows and this model can prove to be very successful if cancellations are predicted correctly.

The second model is also doing the same thing as the first one. The only difference in this case is that the cancellations as well as overbooking are done randomly. The results obtained through table 4 and fig. 3 shows that again the revenue obtained with overbooking is more than the revenue obtained without overbooking. Upon looking at table 3 and 4, along with fig. 3, it can be observed that the profit made due to overbooking are more in case of fixed overbooking as compared to the random overbooking. The profits are more due to the reason that in case of fixed overbooking the cancellation are predicted and then corresponding to those predictions the overbooking are done.

VII. Conclusion

In this paper, two models for overbooking are presented and compared. It has been found that the performance of the first model, which is based on fixed overbooking, is better as compared to the second model, which is based on the random overbooking. In both the cases the revenue obtained is better that the revenue obtained without overbooking. If the cancellations can be predicted correctly, first method should be preferred; otherwise second method of overbooking may be used due to its random nature. Overall both methods can prove to be quite useful in handling overbooking in airline or any other industry where YM is applicable. In future, dynamic overbooking may also be considered, in which the amount of overbooking may change even during booking period depending on the number of cancellations and some other reasons. The overbooking concept may be applied in various industries such as hotels, sea-cargo and even grid computing and cloud computing.

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