“In YM, one of the major problems in maximizing revenue is the number of cancellations. In industries implementing YM this is very common. There are not only cancellations but also no-shows. In case of cancellations, at least the firm knows that seat (inventory) that was booked by a customer will not be utilized by that customer and therefore can be provided to the next customer in waiting. But in case of no-shows, there can be loss of revenue. Therefore some measures needs to be taken to avoid such type of losses. One of that technique is overbooking. The firms can overbook their seats by estimating the cancellation or at random subject to some maximum percentages. The obvious advantage of overbooking will be that revenue which could have been lost due to no-show or cancellations may be recovered up to some extent. But another problem associated with overbooking is the problem of more customers showing-up than the available seats (inventory). Then the firm has to bump some of the customers and pay the penalty accordingly. This chapter looks at these issues and propose simulators first for cancellation and then overbooking using the predicted cancellations. Another simulator using random overbooking has also been presented. The overbooking also takes into account the penalty for bumping a customer.”
8.1 Introduction

The field of airline yield 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. The advance reservation policy is used by the airlines to book the tickets.

The drawback of the advance reservation (AR) system, to both consumers and service providers, is that consumers may either cancel their reservations or simply may not show up at the time when the contracted service is scheduled to be delivered. This will leave some capacity unused, thereby resulting in a loss to service providers. Clearly, this loss can be minimized if service providers do not provide any refund to consumers who either cancel or do not show up. But in this competitive environment, it may not be possible to use such type of measures to avoid loss of revenue.

The drawback of the advance reservation (AR) system, to both consumers and service providers, is that consumers may either cancel their reservations or simply may not show up at the time when the contracted service is scheduled to be delivered. This will leave some capacity unused, thereby resulting in a loss to service providers. Clearly, this loss can be minimized if service providers do not provide any refund to consumers who either cancel or do not show up. But in this competitive environment, it may not be possible to use such type of measures to avoid loss of revenue.

The best way to understand about cancellation or no-shows is to observe airline passengers. Passengers can be divided into business travellers and leisure travellers. Business travellers are most likely to cancel or change their reservations because their travel arrangements depend on others’ schedules and business opportunities. In contrast, students can be sure of their time of travel because they tend to travel during semester breaks and holidays that are not subjected to last-minute changes. All this means is that students are more likely to engage in an advance purchase of discounted non-refundable tickets, whereas business travellers are less likely to commit in advance, and therefore are more likely to either purchase fully refundable tickets or to postpone their ticket purchase to the last minute.

If the cancellation could be estimated in an efficient manner, the revenue of the firm can be increased significantly. The cancellations in airlines industry can be as high as 50%. If this happens the airlines is bound to lose a huge amount of revenue. Therefore it is very important to estimate the cancellations. In the present paper, an attempt has been made to model the estimation of cancellations in airlines booking.

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 chapter, first cancellations are estimated and then using this estimation a model is presented to handle overbooking which is named as fixed overbooking. Another model for overbooking is also presented using random overbooking. The optimal allocations are done by using GA as in chapter 5.

8.2 Background

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 [Rothstein (1971)].

Chatwin (1998) 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 assumed 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. (2002). 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 (2004) 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.

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. It is also possible to develop other methods to avoid no-shows, like customer reminders, deposits, standby passengers, overselling or no money back guarantees. Standby passengers are arriving at the airport and they do not know before the take off time if they will be go with that flight [Shaw, S. (2004)]. The only way that they will travel is if there will be an empty seat, caused by a no-show passenger.

However, overbooking can also cause problems if everyone who had made a reservation turned up. 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 [Cento, A. (2006)]. 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.

Gosavi (2007) 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.

Lan et al. (2011) 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.

8.3 Problem Statement 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. $\sum_{\beta} \sum_{\alpha} N_{\alpha, \beta} F_{\beta}$ ...........................(8.1)

Subject to the constraints

$\sum_{\beta} \sum_{\alpha} N_{\alpha, \beta} \leq C_t$ & $L_{\alpha, \beta} \leq N_{\alpha, \beta} \leq U_{\alpha, \beta}$ for all $\alpha$ and $\beta$,

$N_{\alpha, \beta} \geq 0$,

Where $C_t =$ Total capacity of a flight

$N_{\alpha, \beta} =$ Number of customers belonging to class $\beta$ during time slice $\alpha$.

$F_{\beta} =$ Fare for class $\beta$.

$U_{\alpha, \beta} =$ Upper limit of demand for class $\beta$ during time slice $\alpha$.

$L_{\alpha, \beta} =$ Lower limit of demand for class $\beta$ during time slice $\alpha$.

For estimating the cancellation, the following model is formulated.

Let $\xi$ ($0 < \xi \leq 1$) denote the probability that a consumer with a confirmed reservation actually shows up at the service delivery time. In the technical language, this probability is often referred to as a consumer’s survival probability. It is assumed that all consumers have the same show-up probability, and that a consumer’s show-up probability is independent of all other consumers.

For estimating the expected number of show-ups for each booking level $b$, let the random variable $s$ denote the number of consumers who show up at the service delivery time. Clearly, $s \leq b$, meaning that the number of show-ups cannot exceed the number of bookings. That is, our model does not allow for standby customers and only customers with confirmed reservations are provided with this service. In fact, because $s$ depends on the number of bookings made, $s$ is a function of $b$ and will often be written as $s(b)$. Also, note that $s$ is a random variable, which also depends on the individual’s show-up probability $\xi$, hence it can also be written as $s(b; \xi)$.

The general formula for computing the probability that exactly $c$ consumers show up given that $b$ consumers have confirmed reservations for the service is given by the following binomial distribution function:

$\text{Pr}\{s(b) = c\} = \frac{b!}{c!(b-c)!} \xi^c (1 - \xi)^{(b-c)}$ ...........................(8.2)

Therefore the probability of finding no-shows or cancellations is simply

$\text{Pr}\{Ns\} = 1 - \text{Pr}\{s(b) = c\}$ .................................(8.3)

where $Ns$ indicates the probability of no-shows and/or cancellations.
Let X be the number of no-shows with probability Pr\{Ns\}. 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 up to S+Y tickets. Let the underage penalty be defined by $C_{upen}$ and the overage penalty by $C_{open}$. In this case $C_{open}$ represents the net penalties that are associated with refusing a seat to a passenger holding a confirmed reservation. Here, $C_{upen}$ 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 $C_{upen}$ 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 $C_{open}$. Thus, the formula for optimal number overbooked seats takes following form:

$$F(Y^*) \geq \frac{C_{upen}}{C_{upen} + C_{open}}$$

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. $(\Sigma_{\beta} \Sigma_{\alpha} N_{\alpha, \beta} F_{\beta} - C_{open})$ .........................(8.4)

Subject to the constraints

$\Sigma_{\beta} \Sigma_{\alpha} N_{\alpha, \beta} \leq C_t$ & $L_{\alpha, \beta} \leq N_{\alpha, \beta} \leq U_{\alpha, \beta}$ for all $\alpha$ and $\beta$,

$N_{\alpha, \beta} \geq 0$, $C_{open} \geq 0$.

Where $C_{open}$ = Penalty for bumping a customer.

### 8.4 Simulator for Cancellations and Overbooking

For solving the above formulated problem, a genetic algorithm has been implemented using MATLAB and is stated below:

**Simulator 8.1: SIM_GA_CANCEL** (Simulator using GA for Estimating the Cancellations)

Step 1: $F_c = No\_of\_classes$

Step 2: For $I = 1$ to $F_c$

Step 3: $Init\_pop = Randomly\_Generated\_population$.

Step 4: $curr\_pop = Init\_pop$.

Step 5: While ( !termination\_criterion)

Step 6: Evaluate Fitness of $curr\_pop$ using fitness function.

Step 7: Select mating pool according to Roulette-wheel Selection OR Tournament Selection.

Step 8: Apply Crossovers like One-point, Two-point & Uniform Crossovers on mating pool with probability 0.80.
Step 9: Apply Mutation on mating pool with probability 0.03.
Step 10: Replace generation with \((\lambda + \mu)\)-update as curr_pop.
Step 11: End While
Step 12: \(\xi\) = Survival Probability
Step 13: \(\text{Prob\_show}[I] = \frac{b[I]}{e[(b[I]-c)\xi^{c}(1 - \xi)^{b-c}]}\) \(\text{// Probability of customers showing up}\)
Step 14: \(\text{Prob\_can}[I] = 1 - \text{Prob\_show}[I]\) \(\text{// Cancellation Probability}\)
Step 15: End For
Step 16: End

**Explanation:** This simulator is designed to estimate the cancellations and no-shows. The simulator is designed by assuming the probability distribution for cancellation as Binomial. In this simulator the cancellations and no-show are estimated for each fare class. An example for determining the probability for showing-up and no-show has been given below:

Let us assume that the capacity of airline be 120. Let the cancellations are following binomial distribution. Then the probability of showing-up exactly 118 customers can be calculated as follows:

\[\Pr\{s(120)=118\} = \frac{120!}{118!2!} \xi^{118} (1 - \xi)^{2}\]

If the survival probability \(\xi\) is assumed as 0.99, then

\[\Pr\{s(120)=118\} = 0.2180977445\]

On the basis of this probability the probability of cancellation may be calculated easily.

Next simulator is designed for overbooking using the estimation of cancelled seats obtained using the above simulator. The simulator is known as fixed overbooking simulator.

**Simulator 8.2: SIM\_GA\_FIXOB (Simulator using GA for Fixed Overbooking)**

Step 1: \(F_c = \text{No\_of\_classes}\)
Step 2: \(U_b = \text{Upper\_Bound\_in\_each\_class}\)
Step 3: For \(I = 1\) to \(F_c\)
Step 4: \(U_b = U_b + \text{Prob\_can}[I]\)

\(\text{// Prob\_can}[I]\) is calculated through the simulator for cancellation
Step 5: Init_pop = Randomly Generated population.
Step 6: curr_pop = Init_pop.
Step 7: While ( !termination_criterion)
Step 8: Evaluate Fitness of curr_pop using fitness function.
Step 9: Select mating pool according to Roulette-wheel Selection OR Tournament Selection.
Step 10: Apply Crossovers like One-point, Two-point & Uniform Crossovers on mating pool
with probability 0.80.

Step 11: Apply Mutation on mating pool with probability 0.03.

Step 12: Replace generation with $(\lambda + \mu)$-update as curr_pop.

Step 13: End While

Step 14: Display Revenue with and without overbooking.

Step 15: End

**Explanation:** This simulator works in combination with the earlier simulator. The number of seats to be overbooked are estimated through the cancellations in each class by the previous simulator.

**Simulator 8.3: SIM_GA_RANDOB (Simulator using GA for Random Overbooking)**

Step 1: $F_c = \text{No\_of\_classes}$

Step 2: $U_b = \text{Upper\_Bound\_in\_each\_class}$

Step 3: $\xi = \text{Survival Probability}$

Step 4: For $I = 1$ to $F_c$

Step 5: $\text{Prob\_can}[I] = \text{Random Number between 0 and 1-} \xi$

Step 6: $U_b = U_b + \text{Prob\_can}[I] \times U_b$

Step 7: $\text{Init\_pop} = \text{Randomly Generated population.}$

Step 8: $\text{curr\_pop} = \text{Init\_pop}.$

Step 9: While ( !termination\_criterion)

Step 10: Evaluate Fitness of curr_pop using fitness function.

Step 11: Select mating pool according to Roulette-wheel Selection OR Tournament Selection.

Step 12: Apply Crossovers like One-point, Two-point & Uniform Crossovers on mating pool with probability 0.80.

Step 13: Apply Mutation on mating pool with probability 0.03.

Step 14: Replace generation with $(\lambda + \mu)$-update as curr_pop.

Step 15: End While

Step 16: Display Revenue with and without overbooking.

Step 17: End

**Explanation:** The above simulator presents a simulator with random overbooking. In this case the number of seats to be overbooked is randomly calculated. This simulator is not dependent on simulator 8.1. This is an independent simulator as it is using random overbooking.
8.5 Results and Observations
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 = 50
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 already explained in chapter 5.

**TABLE 8.1: Lower, Upper and Best Estimated Demands in Each Assumed Fare Class**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Fare</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Best Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
<td>63</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>30</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>13</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

The graphs for the optimum results are also shown in fig.8.1 and fig.8.2 similar to chapter 5.

**Fig.8.1: Lower Bound, Upper Bound, and Estimated Fitness**

**Fig.8.2: Average Fitness**
For estimating cancellations, the survival probability is assumed to be 0.7 i.e. chances of showing up each customer are 70%. Upon simulating 100 times, the results obtained for each fare class are shown in table 8.2, 8.3 and 8.4.

**TABLE 8.2 Probability of Cancellation in each Fare Class**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Average % Probability of Cancellation</th>
<th>Standard Deviation</th>
<th>Range of Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>10.9</td>
<td>6.69</td>
<td>4.21 - 17.59</td>
</tr>
<tr>
<td>3</td>
<td>18.8</td>
<td>8.39</td>
<td>10.41 - 27.19</td>
</tr>
<tr>
<td>2</td>
<td>17.9</td>
<td>6.81</td>
<td>11.09 - 24.71</td>
</tr>
<tr>
<td>1</td>
<td>16.7</td>
<td>8.06</td>
<td>8.64 - 24.75</td>
</tr>
</tbody>
</table>

The table 8.2 shows the average probability of cancellations along with the standard deviation in each fare class. This estimation is quite useful for the purpose of overbooking. With the help of this estimation a large amount of revenue loss may be avoided.

**TABLE 8.3 Seat allocation without with Cancellation**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Fare</th>
<th>Optimum Seat Allocation</th>
<th>Average Cancellations</th>
<th>Seats after cancellation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>30</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>45</td>
<td>8</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>20</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

This table 8.3 shows the seat allocation after the predicted cancellation is removed from the optimum solution.

**TABLE 8.4 Comparison of Revenue without and with Cancellation**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Fare</th>
<th>Optimum Revenue</th>
<th>Revenue after cancellation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>3000</td>
<td>2500</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>11250</td>
<td>9250</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>10000</td>
<td>8000</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>4000</td>
<td>3200</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>28250</td>
<td>22950</td>
</tr>
</tbody>
</table>

This table 8.4 compares the optimum revenue with the revenue obtained after cancellations.

The graph for revenue comparison is shown in fig.8.3.
Fig. 8.3  Comparison of Revenue with and without Cancellations

The figure shown above compares the revenue obtained with and without cancellations. It is quite clear from the figure that some revenue may be lost due to cancellations and no-shows. Therefore it becomes necessary to have some means to avoid it or minimize it, if possible.

A sample run of the simulator 8.1 is shown below:

***********Simulation Run***********

enter the number of airplanes: 100
enter the number of fare classes: 4
enter the number of decision periods: 1

Total Revenue with Roulette-Wheel : 28250
Total Revenue with Tournament : 28250

xbest = 5 20 45 30
xbesttour = 5 20 45 30

Cancellation probabilities for classes

20 6 6 16

Canceled seats for classes with above probabilities

0 1 0 3

Seats after cancellation for each classes with Roulette-wheel and Tournament

xrw = 5 19 45 27
xt = 5 19 45 27

Class wise revenue before cancelation for RW and Tournament

prrw = 4000 10000 11250 3000
prt = 4000 10000 11250 3000

Class wise revenue after cancelation for RW and Tournament
\[ \text{rrw} = 4000 \quad 9500 \quad 11250 \quad 2700 \]
\[ \text{rt} = 4000 \quad 9500 \quad 11250 \quad 2700 \]

Total revenue before cancelation for RW and Tournament

28250
28250

Total revenue after cancelation for RW and Tournament

27450
27450

**************End of Simulation Run**************

Next are the simulators for overbooking. Two simulators i.e. 8.2 and 8.3 have been designed in the previous section. The results for these models are given below:

The simulator for overbooking with fixed estimation is executed and the results obtained are shown in table 8.5.

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

This table shows the revenue with and without overbooking, if cancellations are allowed. It is clearly visible from the table that the revenue is increased considerably after overbooking. The profit/loss due to overbooking are also shown in the table. One might be wondering that why the profit/loss is different from the subtraction of the column 4 from column 6. The reason for this is the penalty function i.e. if the number of overbooking are more and less seats are cancelled, then some of the customers needs to be bumped. Hence the airline has to compensate them. In this example a fixed penalty of 200 is assumed per customer irrespective of the fare class.

The revenue comparison with and without fixed overbooking is done in fig. 8.4.
This figure clearly shows the increase in revenue after overbooking.

The sample run of the simulator is shown below:

*********** Simulation Run ***********

enter the number of airplanes: 100  
enter the number of fare classes: 4  
enter the number of decision periods: 1  
obooking = 1 5 12 11  
capacity = 129  
udemand = 6 25 57 74  
Total Revenue with Roulette-Wheel: 35250  
Total Revenue with Tournament: 35250  
xbest = 6 25 57 37  
xbesttour = 6 25 57 37  
Canceled seats for classes with above probabilities  
1 6 7 13  
Seats after cancellation for each classes with Roulette-wheel and Tournament  
xrw = 5 19 45 24  
xt = 5 19 45 24  
xbest = 5 25 57 37  
xbesttour = 5 25 57 37  
xbest = 5 20 45 30  
xbesttour = 5 20 45 30  
Class wise revenue before cancelation for RW and Tournament
prrw = 4000 10000 11250 3000
prt = 4000 10000 11250 3000

Class wise revenue after cancellation for RW and Tournament
rrw = 4000 9500 11250 2400
rt = 4000 9500 11250 2400

Total seats booked after cancellation in RW and tournament
totalseatafterrw = 97
totalseataftert = 97

Total penalty for overbooking in RW and Tournament
  1000
  1000

FINAL

Total revenue without overbooking (after cancelation) for RW and Tournament
  21400
  21400

Total revenue with overbooking (after cancelation) for RW and Tournament
  26550
  26550

*************** End of Simulation Run ***************

The results obtained by executing the second model which implements random overbooking are given in the table 8.6.

This table again show the increase in revenue after random overbooking. Although in this case also revenue has been increased, but not as much as in case of fixed overbooking. This aspect can be clearly observed by looking at the profit/loss column.

**TABLE 8.6: Comparison of Revenue without Overbooking and with Random Overbooking**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Fare</th>
<th>Average No. of Seats Cancelled</th>
<th>Revenue after cancellation and without overbooking</th>
<th>No. of Seats Overbooked</th>
<th>Revenue after cancellation and with overbooking</th>
<th>Profit/Loss due to Overbooking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>2.6 ≈ 3</td>
<td>2700</td>
<td>3</td>
<td>3000</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>1.4 ≈ 1</td>
<td>11000</td>
<td>1.7 ≈ 2</td>
<td>11050</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>1.4 ≈ 1</td>
<td>9500</td>
<td>1.2 ≈ 1</td>
<td>10000</td>
<td>1500</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>0.1 ≈ 0</td>
<td>4000</td>
<td>0.2 ≈ 0</td>
<td>4000</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>26950</td>
<td>28250</td>
<td></td>
<td></td>
<td>1850</td>
</tr>
</tbody>
</table>
The revenue comparison in this case can be seen in figure 8.5.

Fig.8.5: Comparison of Revenue after cancellation (with and without random overbooking)

The sample run for the simulator 8.3 is presented below:

***********Simulation Run***********

enter the number of airplanes: 100
enter the number of fare classes: 4
enter the number of decision periods: 1
overbooking = 0 0 3 12

capacity = 115

demand = 5 20 48 75

Total Revenue with Roulette-Wheel : 29700
Total Revenue with Tournament : 29700

\[ x_{best} = 5 \quad 20 \quad 48 \quad 37 \]

\[ x_{besttourn} = 5 \quad 20 \quad 48 \quad 37 \]

Cancellation probabilities for classes

17 27 20 9

Canceled seats for classes with above probabilities

0 0 9 2

Seats after cancellation for each classes with Roulette-wheel and Tournament
\[
\begin{align*}
x_{rw} &= 5 \\ xt &= 5 \\
\text{Class wise revenue before cancelation for RW and Tournament} \\
p_{rw} &= 4000 \\ p_{rt} &= 4000 \\
\text{Class wise revenue after cancelation for RW and Tournament} \\
r_{rw} &= 4000 \\ r_{rt} &= 4000 \\
\text{Total seats booked after cancelation in RW and tournament} \\
totalseatafterrw &= 99 \\ totalseataftert &= 99 \\
\text{Total penalty for overbooking in RW and Tournament} \\
&= 0 \\
&= 0 \\
\text{Total revenue loss due to overbooking RW and Tournament} \\
&= 500 \\ &+ 500 \\
\text{FINAL} \\
\text{Total revenue without overbooking (after cancellation) for RW and Tournament} \\
&= 25800 \\
&+ 25800
\end{align*}
\]
Total revenue with overbooking (after cancelation) for RW and Tournament

26750

26750

***********************End of Simulation Run***********************

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. 8.6.

![Profit/Loss Comparison of fixed and random overbooking](image)

Fig.8.6: Profit/Loss Comparison of fixed and random overbooking

The above figure shows the difference between the profit/loss with fixed and random overbooking. It can be clearly seen that the profit obtained in revenue is much more in case of fixed overbooking as compared to the profit in case of random overbooking.

8.6 Interpretation

The simulator 8.1 has proved to be successful in predicting the estimates for cancellation and no-shows. The simulator 8.2 used these predictions and overbooked the seats and it has been observed that this model proves to be quite useful in increasing the overall revenue. Another model was also considered which was based on random overbooking and though it also increased the revenue but not as much as the fixed overbooking model does. Overall it can be said that if the cancellations are following binomial distribution, then the simulator 8.2 can be used successfully.

8.7 Summary

This chapter presents the three simulators for the purpose of estimating the cancellations and handling the overbooking. The first simulator which uses binomial distribution as the pattern for cancellation estimates the number of cancellations. The second simulator uses first simulator and overbooks the seats accordingly. It has been found that the revenue is increased considerably using this model which is named as fixed overbooking. Another simulator has
also been presented that used the concept of random overbooking. This simulator also provides good results. But upon comparing the two models, it has been observed that first model proves to be better than the first model. Overall the problem of cancellations and overbooking has been taken care of in this chapter.