GMAN 505: Forecasting and Operations Management

Class 9:

Revenue (Yield) Management

Some U.S. airline industry observations

- Since deregulation (1978) 137 carriers have filed for bankruptcy.
- From 95-99 (the industry's best 5 years ever) airlines earned 3.5 cents on each dollar of sales:
  - The US average for all industries is around 6 cents.
  - From 90-99 the industry earned 1 cent per $ of sales.
- Carriers typically fill 72.4% of seats and have a break-even load of 70.4%.

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Matching supply to demand when supply is fixed

- Examples of fixed supply:
  - Travel industries (fixed number of seats, rooms, cars).
  - Advertising time (limited number of time slots).
  - Telecommunications bandwidth.
  - Size of the MBA program.
  - Doctor's availability for appointments.
- Revenue management is a solution:
  - If adjusting supply is impossible – adjust the demand!
  - Segment customers into high willingness to pay and low willingness to pay.
  - Limit the number of tickets sold at a low price
  - Control the average price by changing the mix of customers.

Environments suitable for revenue management

- Rigid capacity without the possibility to store excess products or services.
- Decision has to be made before uncertainty in demand is resolved.
- There is an opportunity to segment customers (so that different prices can be charged).
- The same unit of capacity (e.g., airline seat) can be used to deliver services to different customer segments (e.g., business and leisure customers) at different prices.
- It is not illegal or morally irresponsible to discriminate among customers.

Practical problem

- The Sir Francis Drake Hotel in San Francisco.
  - 118 King/Queen rooms.
- Hyatt offers a $r_L = \$159$ (low fare) discount fare for a mid-week stay targeting leisure travelers.
  - Demand for low fare rooms is abundant.
- Regular fare is $r_H = \$225$ (high fare) targeting business travelers.
- Let *D* be *uncertain* demand for high fare rooms.
  - Suppose *D* has Poisson distribution with mean 27.3.
- Assume most of the high fare (business) demand occurs only within a few days of the actual stay.
- Objective:
  - Maximize expected revenues by controlling the number of low fare rooms you sell.

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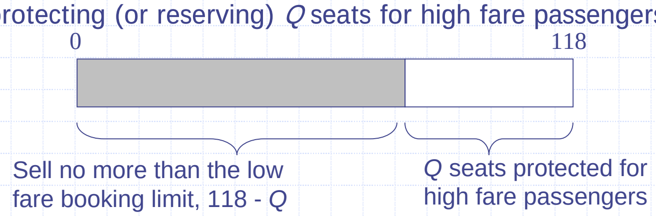
Yield management decisions

- The *booking limit* is the number of rooms you are willing to sell in a fare class or lower.
- The *protection level* is the number of rooms you reserve for a fare class or higher.
- Let *Q* be the protection level for the high fare class.
- *Q* is in effect while you sell low fare tickets.
- Since there are only two fare classes, the booking limit on the low fare class is 118 – *Q*:
  - You will sell no more than 118-*Q* low fare tickets because you are protecting (or reserving) *Q* seats for high fare passengers.



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The connection to the newsvendor

- A single decision is made before uncertain demand is realized.
- There is an overage penalty:
  - If $D < Q$ then you protected too many rooms (you over protected) ...
  - ... so some rooms are empty which could have been sold to a low fare traveler.
- There is an underage penalty:
  - If $D > Q$ then you protected too few rooms (you under protected) ...
  - ... so some rooms could have been sold at the high fare instead of the low fare.
- Choose Q to balance the overage and underage penalties.

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Optimal protection level

- Overage penalty:
  - If $D < Q$ we protected too many rooms and earn nothing on $Q - D$ rooms while incurring $C_o = r_L$ penalty on each room we did not sell.
- Underage penalty:
  - If $D > Q$ we protected too few rooms and forgo $C_u = r_H - r_L$ in revenue on each rooms that we could have sold at a higher price
- Optimal high fare protection level:

$$F(Q^*) = \frac{C_u}{C_o + C_u} = \frac{r_H - r_L}{r_H}.$$

- Optimal low fare booking limit = 118 – Q^*
- Choosing the optimal high fare protection level is a Newsvendor problem with properly chosen underage and overage penalties.

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Sir Francis Drake example

- Critical ratio: $\frac{C_u}{C_o + C_u} = \frac{r_h - r_l}{r_h} = \frac{225-159}{225} = \frac{66}{225} = 0.2933$

- Poisson distribution with mean 27.3:

Q	F(Q)	Q	F(Q)	Q	F(Q)
10	0.0001	20	0.0920	30	0.7365
11	0.0004	21	0.1314	31	0.7927
12	0.0009	22	0.1802	32	0.8406
13	0.0019	23	0.2381	33	0.8803
14	0.0039	24	0.3040	34	0.9121
15	0.0077	25	0.3760	35	0.9370
16	0.0140	26	0.4516	36	0.9558
17	0.0242	27	0.5280	37	0.9697
18	0.0396	28	0.6025	38	0.9797
19	0.0618	29	0.6726	39	0.9867

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Related problems

- How many high-fare travelers will be refused a reservation?
  - *Expected lost sales* = 4.10.
- How many high-fare travelers will be accommodated?
  - *Expected sales* = *Expected demand* - *Lost sales* = 27.3 - 4.1 = 23.2
- How many seats will remain empty?
  - *Expected left over inventory* = *Q* - *Expected sales* = 24 - 23.2 = 0.8.
- What is the expected revenue?
  - \$225 x *Exp. sales* + \$159 x *Booking limit* = \$20,166.
  - Note: without yield management worst case scenario is \$159 x 118 = \$18,762.

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Sir Francis Drake's Problem

- The forecast for the number of customers that do not show up (X) is Poisson with mean 8.5.
- The cost of denying a room to the customer with a confirmed reservation is $350 in ill-will and penalties.
- How many rooms (Y) should be overbooked (sold in excess of capacity)?
- Newsvendor setup:
  - Single decision when the number of no-shows in uncertain.
  - Underage penalty if $X > Y$ (insufficient number of seats overbooked).
  - Overage penalty if $X < Y$ (too many seats overbooked).

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Overbooking solution

- Underage penalty:
  - if $X > Y$ then we could have sold X-Y more rooms...
  - ... to be conservative, we could have sold those rooms at the low fare, $C_u = r_L$.
- Overage penalty:
  - if $X < Y$ then we bumped Y - X customers ...
  - ... and incur an overage penalty C_o = $350 on each bumped customer.
- Optimal overbooking level: $F(Y) = \dfrac{C_u}{C_o + C_u}$.
- Critical ratio: $\dfrac{C_u}{C_u + C_o} = \dfrac{159}{350 + 159} = 0.3124$

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Optimal overbooking level

- Poisson distribution with mean 8.5

Q	F(Q)	Q	F(Q)
0	0.0002	10	0.7634
1	0.0019	11	0.8487
2	0.0093	12	0.9091
3	0.0301	13	0.9486
4	0.0744	14	0.9726
5	0.1496	15	0.9862
6	0.2562	16	0.9934
7	0.3856	17	0.9970
8	0.5231	18	0.9987
9	0.6530	19	0.9995

- Optimal number of overbooked rooms is Y=7.
- Hyatt should allow up to 118+7 reservations.
- There is about $F(6)$=25.62% chance that Hyatt will find itself turning down travelers with reservations.

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Summary

- Yield management and overbooking give demand flexibility where supply flexibility is not possible.
- The Newsvendor model can be used:
  - Single decision in the face of uncertainty.
  - Underage and overage penalties.
- These are powerful tools to improve revenue:
  - American Airlines estimated a benefit of $1.5B over 3 years.
  - National Car Rental faced liquidation in 1993 but improved via yield management techniques.
  - Delta Airlines credits yield management with $300M in additional revenue annually (about 2% of year 2000 revenue.)

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Discussion of other RM applications

- Grocery retailer?
- Internet provider allocating bandwidth to customers?
- Distribution of blood supply in a hospital?
- University of Pennsylvania deciding to grant early admission to a student?
- Physician’s office scheduling appointments?
- More?

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