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Introduction to Revenue Management: Flight Leg Revenue Optimization

16.75 Airline Management

Dr. Peter P. Belobaba

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Lecture Outline

1. **Airline Revenue Maximization**
   - Pricing vs. Yield (Revenue) Management
2. **Computerized RM Systems**
   - RM System in ePODS
3. **Single-leg Fare Class Seat Allocation Problem**
   - Partitioned vs. Serial Nesting of Booking Classes
   - Deterministic vs. Probabilistic Demand
4. **EMSRb Model for Seat Protection**
   - Example of Calculations

1. Airline Revenue Maximization

- **Two components of airline revenue maximization:**

  Differential Pricing:
  - Various “fare products” offered at different prices for travel in the same O-D market

  Yield Management (YM):
  - Determines the number of seats to be made available to each “fare class” on a flight, by setting booking limits on low fare seats

- **Typically, YM takes a set of differentiated prices/products and flight capacity as given:**
  - With high proportion of fixed operating costs for a committed flight schedule, revenue maximization to maximize profits

Why Call it "Yield Management"?

- **Main objective of YM is to <u>protect seats</u> for later-booking, high-fare business passengers.**
- **YM involves tactical control of airline's seat inventory:**
  - But too much emphasis on <u>yield</u> (revenue per RPM) can lead to overly severe limits on low fares, and lower overall load factors
  - Too many seats sold at lower fares will increase load factors but reduce yield, adversely affective total revenues
- **<u>Revenue</u> maximization is proper goal:**
  - Requires proper balance of load factor and yield
- **Many airlines now refer to "Revenue Management" (RM) instead of "Yield Management"**

Seat Inventory Control Approaches

EXAMPLE: 2100 MILE FLIGHT LEG **CAPACITY = 200**

NUMBER OF SEATS SOLD:

FARE CLASS	AVERAGE REVENUE	YIELD EMPHASIS	LOAD FACTOR EMPHASIS	REVENUE EMPHASIS
Y	$420	20	10	17
B	$360	23	13	23
H	$230	22	14	19
V	$180	30	55	37
Q	$120	15	68	40
	TOTAL PASSENGERS	110	160	136
	LOAD FACTOR	55%	**80%**	68%
	TOTAL REVENUE	$28,940	$30,160	**$31,250**
	AVERAGE FARE	$263	$189	$230
	YIELD (CENTS/RPM)	**12.53**	8.98	10.94

Revenue Management Techniques

- **Overbooking**
  - Accept reservations in excess of aircraft capacity to overcome loss of revenues due to passenger “no-show” effects
- **Fare Class Mix (Flight Leg Optimization)**
  - Determine revenue-maximizing mix of seats available to each booking (fare) class on each flight departure
- **Traffic Flow (O-D) Control (Network Optimization)**
  - Further distinguish between seats available to short-haul (one-leg) vs. long-haul (connecting) passengers, to maximize total network revenues
  - Currently under development by some airlines

2. Computerized RM Systems

- **Size and complexity of a typical airline's seat inventory control problem requires a computerized RM system**
- **Consider a US Major airline with:**

  2000 flight legs per day

  10 booking classes

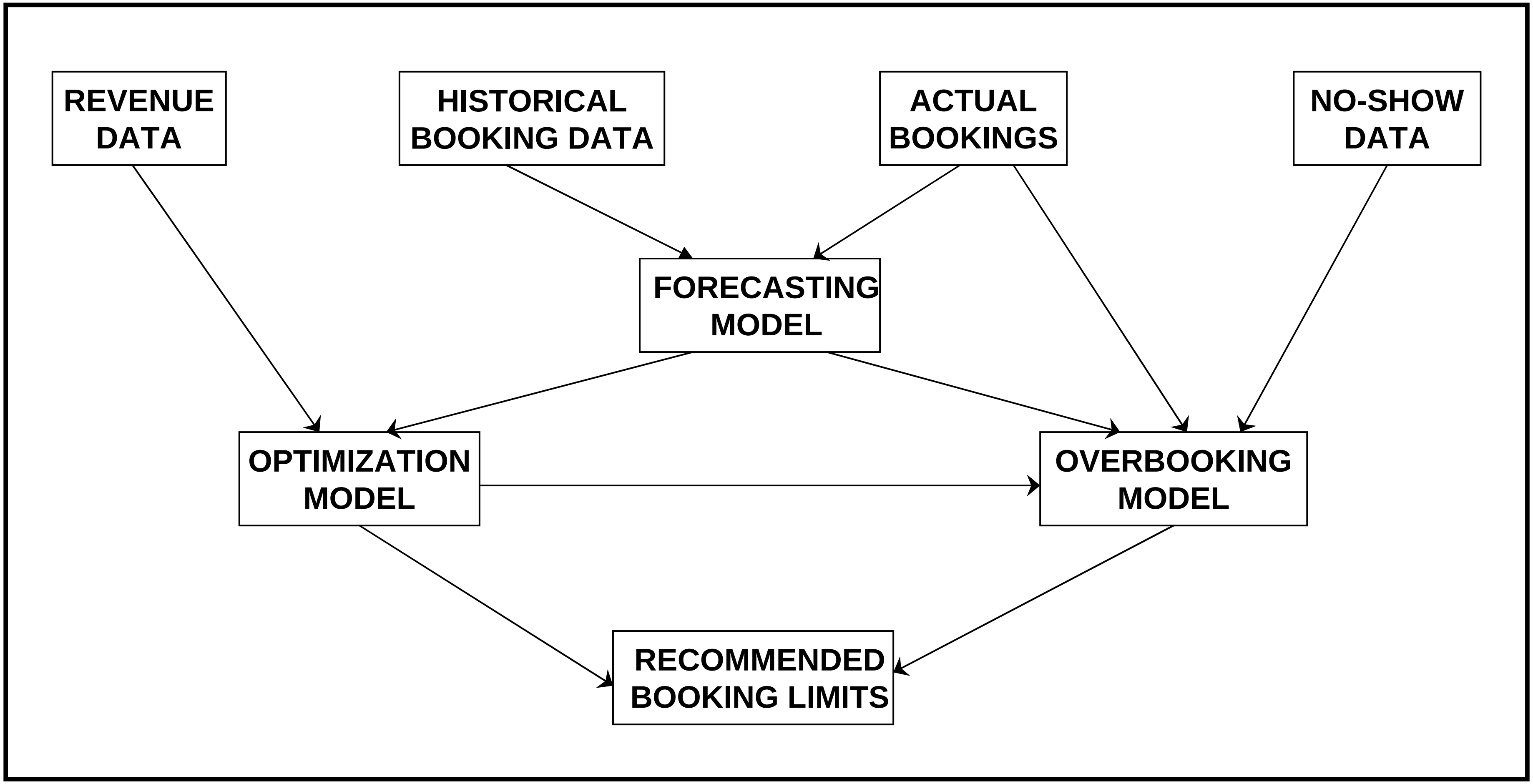
  300 days of bookings before departure

- **At any point in time, this airline's seat inventory consists of 6 million booking limits:**
  - **This inventory represents the airline's potential for profitable operation, depending on the revenues obtained**
  - **Far too large a problem for human analysts to monitor alone**

Typical 3rd Generation RM System

- Collects and maintains historical booking data by flight and fare class, for each past departure date.
- Forecasts future booking demand and no-show rates by flight departure date and fare class.
- Calculates limits to maximize total flight revenues:
  - Overbooking levels to minimize costs of spoilage/denied boardings
  - Booking class limits on low-value classes to protect high-fare seats
- Interactive decision support for RM analysts:
  - Can review, accept or reject recommendations

Example of Third Generation RM System



Dynamic Revision and Intervention

- **RM systems revise forecasts and re-optimize booking limits at numerous "checkpoints" of the booking process:**
  - Monitor actual bookings vs. previously forecasted demand
  - Re-forecast demand and re-optimize at fixed checkpoints or when unexpected booking activity occurs
  - Can mean substantial changes in fare class availability from one day to the next, even for the same flight departure
- **Substantial proportion of fare mix revenue gain comes from dynamic revision of booking limits:**
  - Human intervention is important in unusual circumstances, such as "unexplained" surges in demand due to special events

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Current State of RM Practice

- Most of the top 25 world airlines (in terms of revenue) have implemented 3rd generation RM systems.
- Many smaller carriers are still trying to make effective use of leg/fare class RM
  - Lack of company-wide understanding of RM principles
  - Historical emphasis on load factor or yield, not revenue
  - Excessive influence and/or RM abuse by dominant sales and marketing departments
  - Issues of regulation, organization and culture
- About a dozen leading airlines are looking toward network O-D control development and implementation
  - These carriers could achieve a 2-5 year competitive advantage with advanced revenue management systems

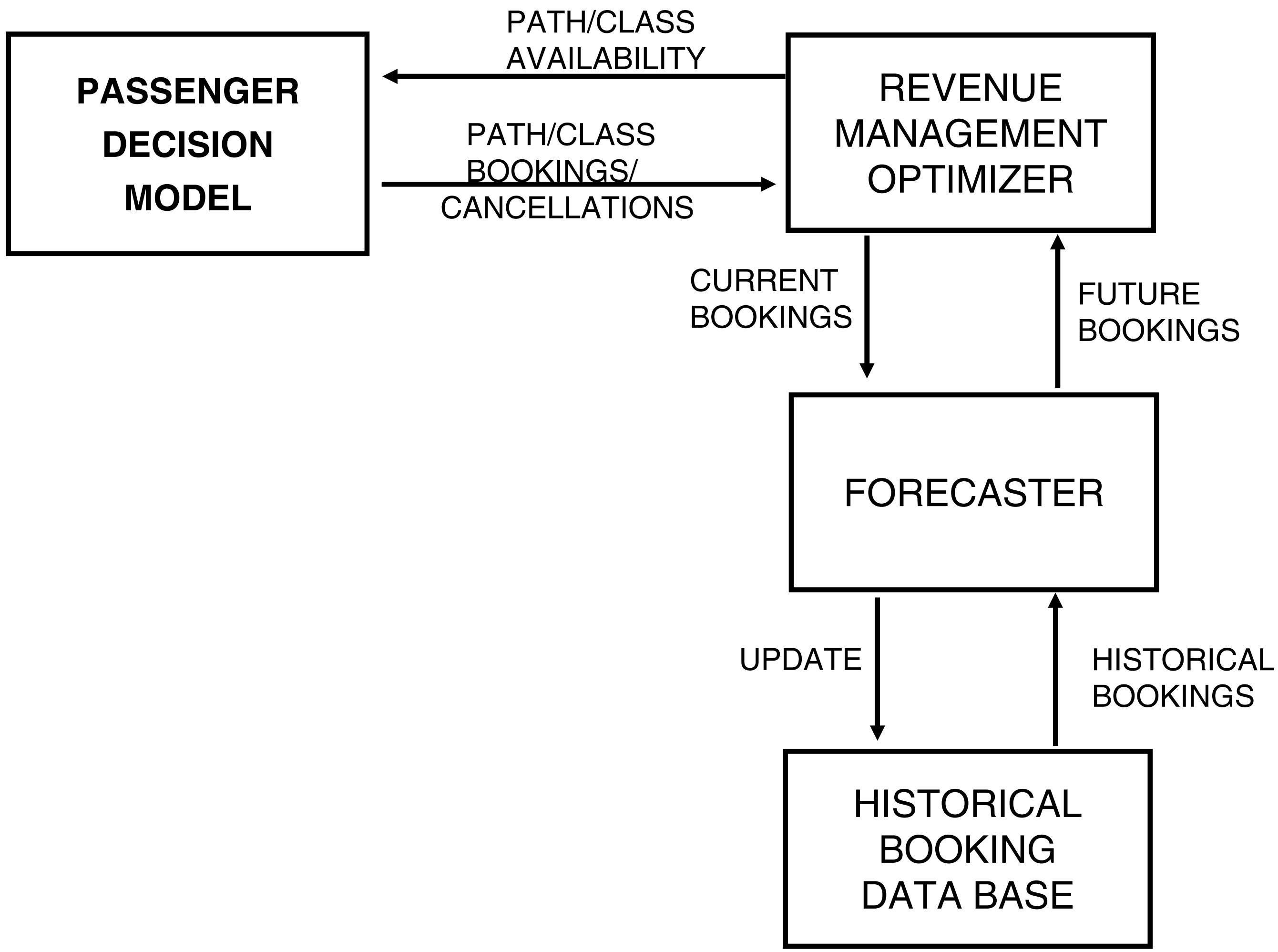
"Vanilla" RM System in ePODS

- **Airlines' RM systems forecast fare class demand for each flight leg departure:**
  - Simple "pick-up" forecasts of bookings still to come
  - Unconstraining of closed observations based on booking curve probabilities.
- **Optimization is leg-based EMSRb seat protection algorithm:**
  - Booking limits set for each fare class on each flight leg departure, revised 16 times during booking process.
- **No overbooking or no-shows in ePODS.**

Revenue Management Intervention

- ePODS replicates airline RM system actions over time, taking into account previous interventions:
  - Previously applied booking limits affect actual passenger loads and, in turn, future demand forecasts
- "Historical" booking data is used to generate forecasts for "future" departures.
- RM system <u>only</u> uses data available from past observations.

PODS Simulation: Basic Schematic



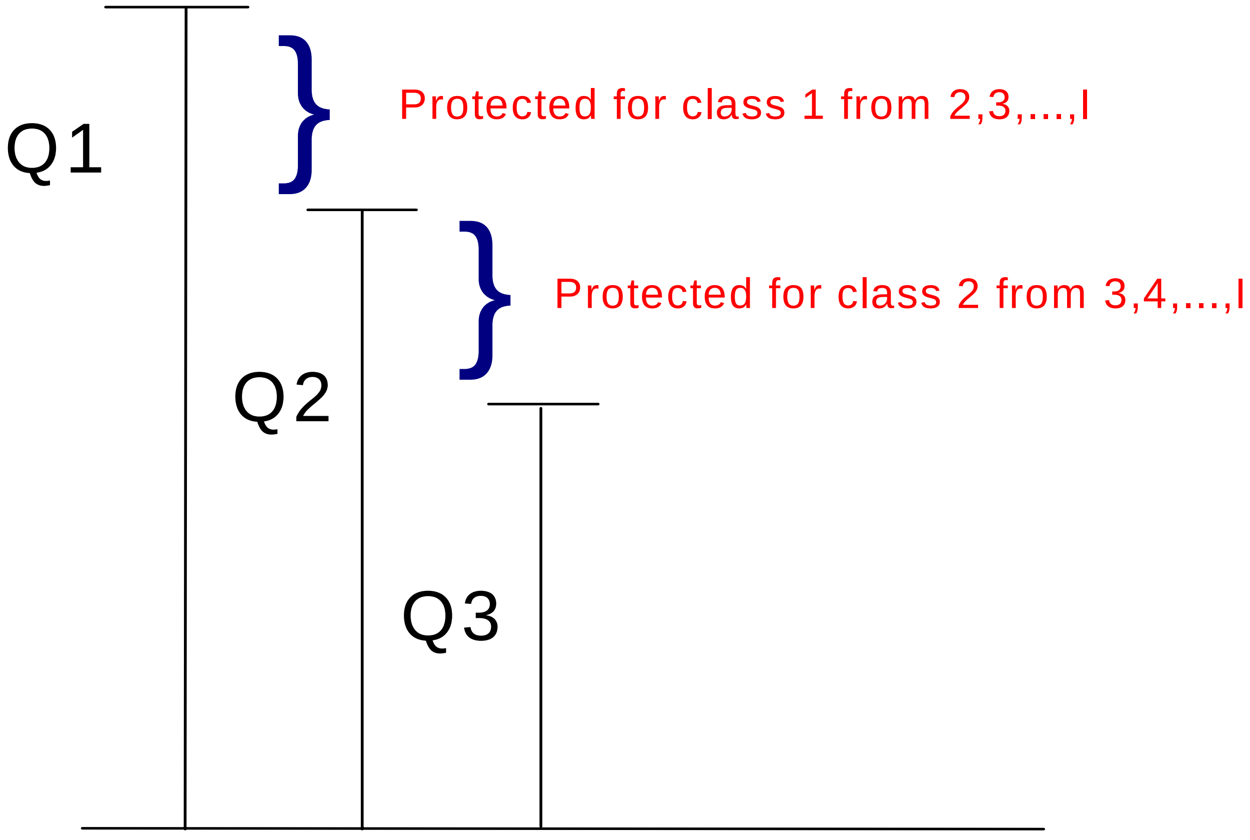
3. Single-Leg Seat Allocation Problem

- **Given for a future flight leg departure:**
  - Total booking capacity of (typically) the coach compartment
  - Several fare (booking) classes that share the same inventory of seats in the compartment
  - Forecasts of future booking demand by fare class
  - Revenue estimates for each fare (booking) class
- **Objective is to maximize total expected revenue:**
  - Allocate seats to each fare class based on value

Partitioned vs. Serial Nesting

- In a partitioned CRS inventory structure, allocations to each booking class are made separately from all the other classes.
- <u>EXAMPLE</u> (assuming uncertain demand):
  - Given the following allocations for each of 3 classes--Y = 30, B = 40, M = 70 for an aircraft coach cabin with booking capacity = 140.
  - If 31 Y customers request a seat, the airline would reject the 31st request because it exceeds the allocation for the Y class
  - It is possible that airline would reject the 31st Y class customer, even though it might not have sold all of the (lower-valued) B or M seats yet!
- Under serial nesting of booking classes, the airline would never turn down a Y fare request, as long as there are any seats (Y, B or M) left for sale.

Serially Nested Buckets



Deterministic Seat Allocation/Protection

- **If we assume that demand is deterministic (or known with certainty), it would be simple to determine the fare class seat allocations**
  - Start with highest fare class and allocate/protect exactly the number of seats predicted for that class, and continue with the next lower fare class until capacity is reached.
- **EXAMPLE: 3 fare classes (Y, B, M)**
  - Demand for Y = 30, B = 40, M = 85
  - Capacity = 140
- **Deterministic decision: Protect 30 for Y, 40 for B, and allocated 70 for M (i.e., spill 15 M requests)**
- **Nested booking limits Y=140 B=110 M=70**

EMSRb Model for Seat Protection: Assumptions

- **Basic modeling assumptions for serially nested classes:**
  - a) demand for each class is separate and independent of demand in other classes.
  - b) demand for each class is stochastic and can be represented by a probability distribution
  - c) lowest class books first, in its entirety, followed by the next lowest class, etc.
  - d) booking limits are only determined once (i.e., static optimization model)

EMSRb Model Calculations

- **Because higher classes have access to unused lower class seats, the problem is to find seat <u>protection levels</u> for higher classes, and <u>booking limits</u> on lower classes**
- **To calculate the optimal protection levels:**

  Define $P_i(S_i) =$ probability that $X_i \geq S_i$,

  where S_i is the number of seats made available to class i, X_i is the random demand for class i

EMSRb Calculations (cont'd)

- **The expected marginal revenue of making the Sth seat available to class i is:**
  - **$EMSR_i(S_i) = R_i * P_i(S_i)$ where R_i is the average revenue (or fare) from class i**
- **The optimal protection level, π_1 for class 1 from class 2 satisfies:**
  - **$EMSR_1(\pi_1) = R_1 * P_1(\pi_1) = R_2$**
- **Once π_1 is found, set BL_2 = Capacity - π_1. Of course, BL_1 = Capacity (authorized capacity if overbooking)**

Example Calculation

Consider the following flight leg example:

Class	Mean Fcst.	Std. Dev.	Fare
Y	10	3	1000
B	15	5	700
M	20	7	500
Q	30	10	350

- **To find the protection for the Y fare class, we want to find the largest value of π_Y for which**

$$EMSR_Y(\pi_Y) = R_Y * P_Y(\pi_Y) \geq R_B$$

Example (cont'd)

$$EMSR_Y(\pi_Y) = 1000 * P_Y(\pi_Y) \geq 700$$
$$P_Y(\pi_Y) \geq 0.70$$

where $P_Y(\pi_Y)$ = probability that $X_Y \geq \pi_Y$.

- **If we assume demand in Y class is *normally* distributed with mean, standard deviation given earlier, then we can create a standardized normal random variable as (X_Y - 10)/3.**

Probability Calculations

- **Next, we use Excel or go to the Standard Normal Cumulative Probability Table for different "guesses" for $\pi_{Y.}$ For example,**

  for $\pi_Y = 7$, Prob { $(X_Y - 10)/3 \geq (7 - 10)/3$ } = 0.841

  for $\pi_Y = 8$, Prob { $(X_Y - 10)/3 \geq (8 - 10)/3$ } = 0.747

  for $\pi_Y = 9$, Prob { $(X_Y - 10)/3 \geq (9 - 10)/3$ } = 0.63

- **So, we can see that $\pi_Y = 8$ is the largest integer value of π_Y that gives a probability ≥ 0.7 and therefore we will protect 8 seats for Y class!**

Joint Protection for Classes 1 and 2

- How many seats to protect jointly for classes 1 and 2 from class 3?
- The following calculations are necessary:

$$\overline{X}_{1,2} = \overline{X}_1 + \overline{X}_2$$

$$\hat{\sigma}_{1,2} = \sqrt{\hat{\sigma}_1^2 + \hat{\sigma}_2^2}$$

$$R_{1,2} = \frac{R_1 * \overline{X}_1 + R_2 * \overline{X}_2}{\overline{X}_{1,2}}$$

$$P_{1,2}(S) = \Pr ob(X_1 + X_2 > S)$$

Protection for Y+B Classes

- To find the protection for the Y and B fare classes from M, we want to find the largest value of π_{YB} that makes

$$EMSR_{YB}(\pi_{YB}) = R_{YB} * P_{YB}(\pi_{YB}) \geq R_M$$

- Intermediate Calculations:

$R_{YB} =$ (10*1000 + 15 *700)/ (10+15) = 820

$$\overline{X}_{Y,B} = \overline{X}_Y + \overline{X}_B = 10 + 15 = 25$$

$$\hat{\sigma}_{Y,B} = \sqrt{\hat{\sigma}_Y^2 + \hat{\sigma}_B^2} = \sqrt{3^2 + 5^2} = \sqrt{34} = 5.83$$

Example: Joint Protection

- **The protection level for Y+B classes satisfies:**

  $820 * P_{YB}(\pi_{YB}) \geq 500$

  $P_{YB}(\pi_{YB}) \geq .6098$

- **Again, we can make different "guesses" for π_{YB}.**

for $\pi_{YB} = 20$, Prob $\{ (X_{YB} - 25)/5.83 \geq (20 - 25)/5.83 \} = 0.805$

for $\pi_{YB} = 22$, Prob $\{ (X_{YB} - 25)/5.83 \geq (22 - 25)/5.83 \} = 0.697$

for $\pi_{YB} = 23$, Prob $\{ (X_{YB} - 25)/5.83 \geq (23 - 25)/5.83 \} = 0.633$

for $\pi_{YB} = 24$, Prob $\{ (X_{YB} - 25)/5.83 \geq (24 - 25)/5.83 \} = 0.5675$

Joint Protection for Y+B

- So, we can see that π_{YB} = 23 is the largest integer value of π_{YB} that gives a probability $\geq$ 0.6098 and therefore we will jointly protect 23 seats for Y and B class from class M!
- Suppose we had an aircraft with authorized booking capacity 80 seats, our Booking Limits would be:

  $BL_Y = 80$

  $BL_B = 80 - 8 = 72$

  $BL_M = 80 - 23 = 57$

General Case for Class n

- How many seats to protect jointly for classes 1 through n from class n+1?
- The following calculations are necessary:

$$\overline{X}_{1,n} = \sum_{i=1}^{n} \overline{X}_i$$

$$\hat{\sigma}_{1,n} = \sqrt{\sum_{i=1}^{n} \hat{\sigma}^2_i}$$

$$R_{1,n} = \frac{\sum_{i=1}^{n} R_i * \overline{X}_i}{\overline{X}_{1,n}}$$

General Case (cont'd)

- We then find the value of π_n that makes

  $$EMSR_{1,n}(\pi_n) = R_{1,n} * P_{1,n}(\pi_n) = R_{n+1}$$

- Once π_n is found, set $BL_{n+1} = \text{Capacity} - \pi_n$