Evolution of Airline Revenue Management

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Lecture Outline

1. **Review: Airline Pricing**
   - Differential Pricing Theory
2. **Revenue Management Systems**
   - Load Factor vs. Yield Strategies
   - RM System Components
3. **Single-leg Fare Class Seat Allocation Problem**
   - EMSRb Model for Seat Protection
4. **Overbooking Models and Practice**
   - Mathematical Approaches to Overbooking
   - Denied Boarding vs. Spoilage Costs

Airline Revenue Maximization

Differential Pricing:

- Various "fare products" offered at different prices for travel in the same O-D market

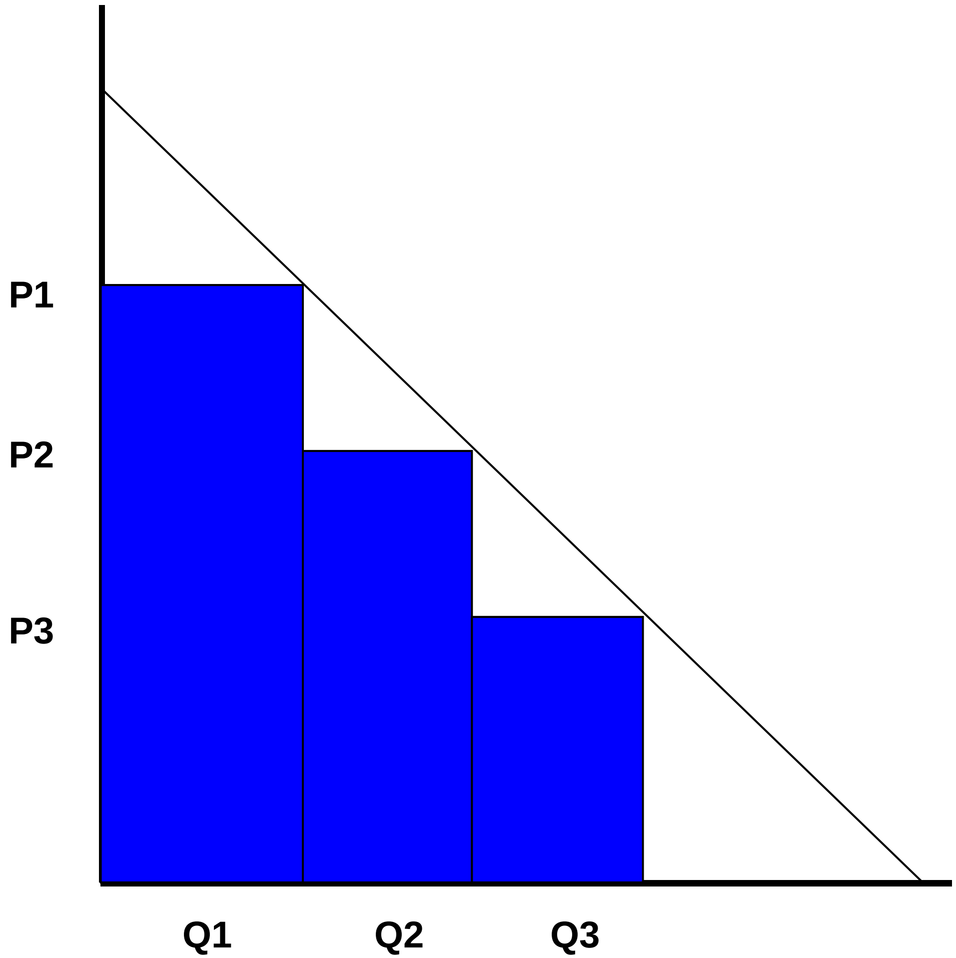
Revenue Management (RM):

- Determines the number of seats to be made available to each "fare class" on a flight, by setting booking limits on low fare seats

- **With high proportion of fixed operating costs for a schedule, maximize revenues to maximize profits**

- **With very few exceptions, virtually *all airlines* make use of differential pricing and RM:**
  - Including most new entrant Low-Cost Carriers (LCCs) with "simpler" fares

Differential Pricing Theory



- **Market segments with different "willingness to pay" for air travel**
- **Different "fare products" offered to business versus leisure travelers**
- **Prevent diversion by setting restrictions on lower fare products and limiting seats available**
- **Increased revenues and higher load factors than any single fare strategy**

BOS-IST Economy Class Fare Structure
Turkish Airlines, April 2015

Class	One Way Fare	Advance Purchase	Minimum Stay	Change Fee	Refunds	RT Required
Y	$1072	None	None	None	Yes	No
B	$934	None	None	None	Yes	No
M	$725	0/3 (TKT)	Sat Night	$135	No	Yes
H	$612	0/3 (TKT)	Sat Night	$135	No	Yes
S	$512	0/3 (TKT)	Sat Night	$135	No	Yes
E	$425	0/3 (TKT)	Sat Night	$135	No	Yes
Q	$350	0/3 (TKT)	Sat Night	$135	No	Yes
L	$238	0/3 (TKT)	Sat Night	$135	No	Yes

Yield Management = Revenue Management

- **Primary objective is to protect seats for late-booking high-fare demand, given limited capacity:**
  - Forecast future booking demand for each fare product
  - Optimize number of seats to be made available to each fare class
- **Optimal control of available seat inventory:**
  - On high demand flights, limit discount fare and group bookings to increase overall yield (average fare) and revenue.
  - On low demand flights, sell empty seats at any low fare to increase load factors and revenue.
  - <u>Revenue</u> maximization requires a balance of yield and load factor
- **Balance yield vs. load factor to maximize revenues**

Revenue Management Strategies

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

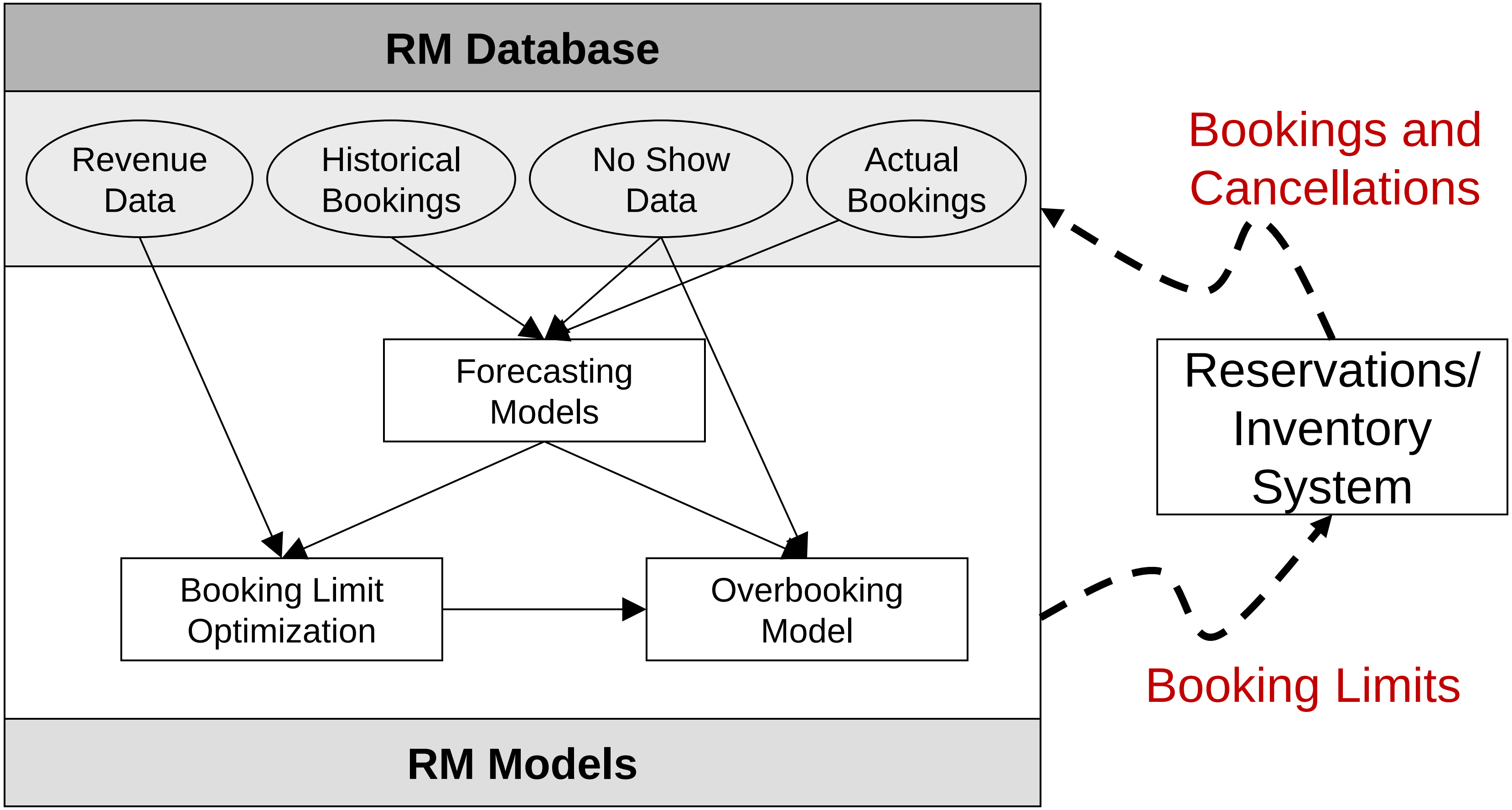
NUMBER OF SEATS SOLD:

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

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

Third Generation Leg-based RM System



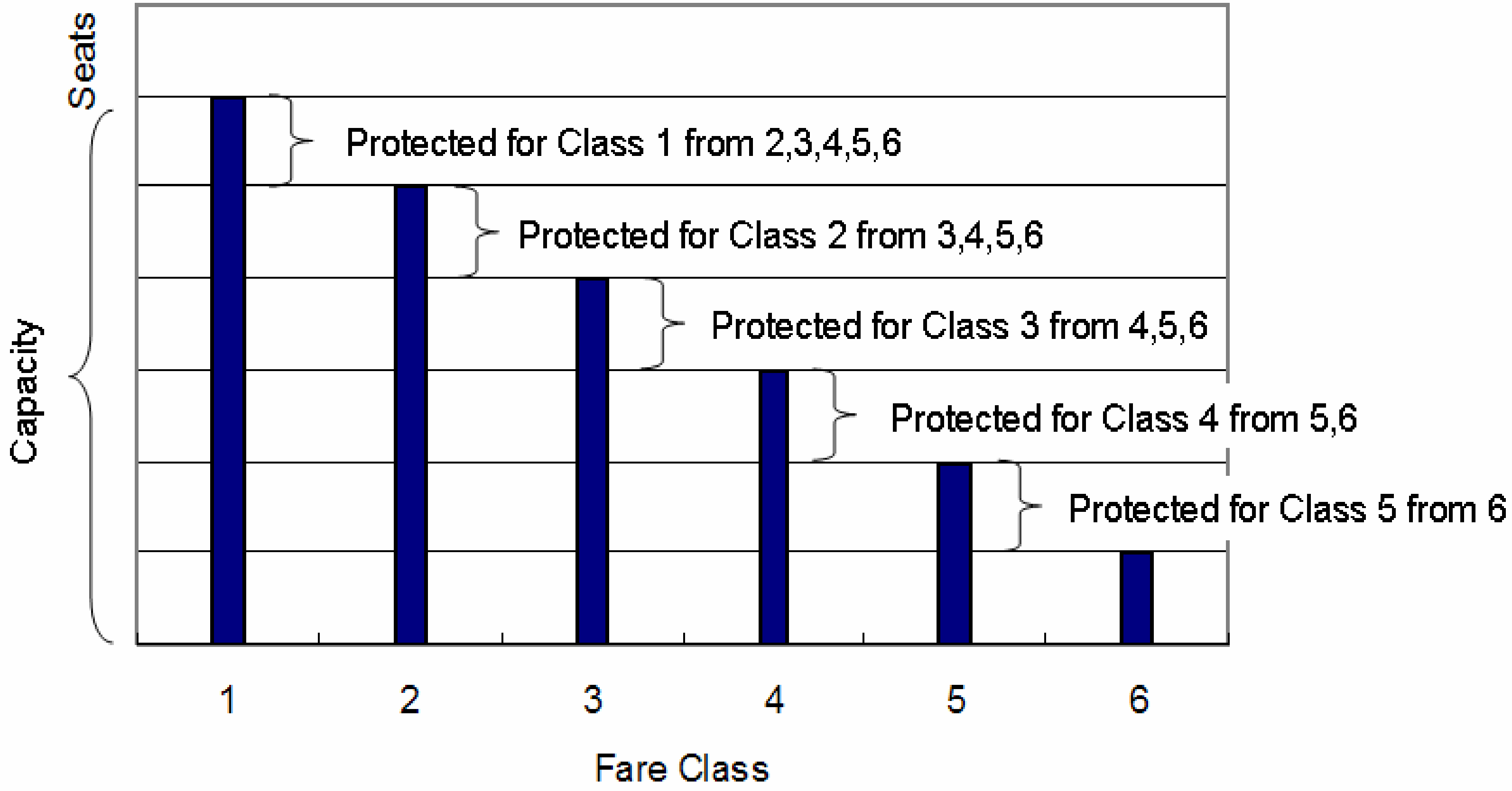
Components of 3rd Generation RM

- **Demand Forecasting**
  - Time series methods applied to historical booking data to forecast demand by fare class for each future flight/departure date
- **Flight Leg Optimization**
  - Expected Marginal Seat Revenue (EMSR) models determine revenue-maximizing mix of seats for each fare class
- **Overbooking**
  - Cost-based overbooking models minimize denied boarding and spoilage costs, based on probabilistic analysis of no-shows
- **Revenue increases of 4 to 6 percent typically quoted**
  - From overbooking and fare class mix optimization alone

Leg-Based Fare Class Mix Optimization

- **Determine the optimal number of seats to make available to each booking class.**
- **Given for each future flight leg departure:**
  - Total remaining booking capacity of (typically) the coach compartment
  - Forecasts of future booking demand by fare class between current DCP and departure
  - Revenue estimates for each fare (booking) class
- **Objective is to maximize total expected revenue:**
  - Protect seats for each fare class based on revenue value, taking into account forecast uncertainty and probability of realizing the forecasted demand

Serially Nested Buckets



EMSRb Model Calculations

- **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

- **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:**

  $EMSR_1(\pi_1) = R_1 * P_1(\pi_1) = R_2$

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 $X_Y \geq \pi_Y$.

- **Assume demand in Y class is *normally* distributed, then we can create a standardized normal random variable as $(X_Y - 10)/3$:**

  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

- **$\pi_Y = 8$ is the largest integer value of π_Y that gives a probability $\geq$ 0.7 and we will protect 8 seats for Y class.**

General Case for Class n

- **Joint protection for classes 1 through n from class n+1**

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

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

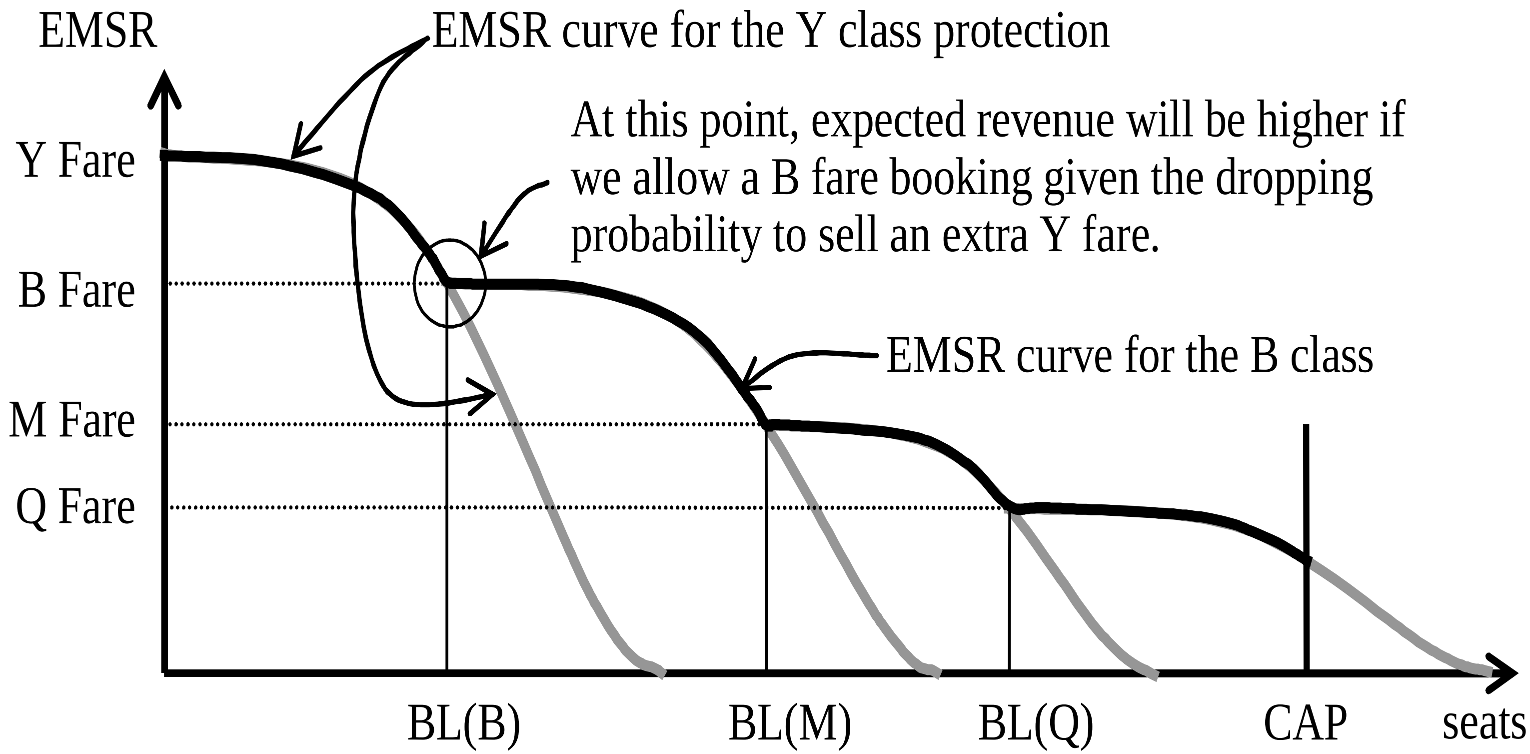
$$R_{1,n} = \frac{\sum_{i=1}^{n} R_i * \overline{X}_i}{\overline{X}_{1,n}}$$

- **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}= Capacity - π_n**

Graphical Representation of EMSR Curves and Booking Limits



EMSRb Seat Protection Model

CABIN CAPACITY =		135				
AVAILABLE SEATS =		135				
BOOKING	AVERAGE	SEATS	FORECAST DEMAND		JOINT	BOOKING
CLASS	FARE	BOOKED	MEAN	SIGMA	PROTECT	LIMIT
Y	$ 670	0	12	7	6	135
M	$ 550	0	17	8	23	129
B	$ 420	0	10	6	37	112
V	$ 310	0	22	9	62	98
Q	$ 220	0	27	10	95	73
L	$ 140	0	47	14		40
	SUM	0	135			

Dynamic Revision and Intervention

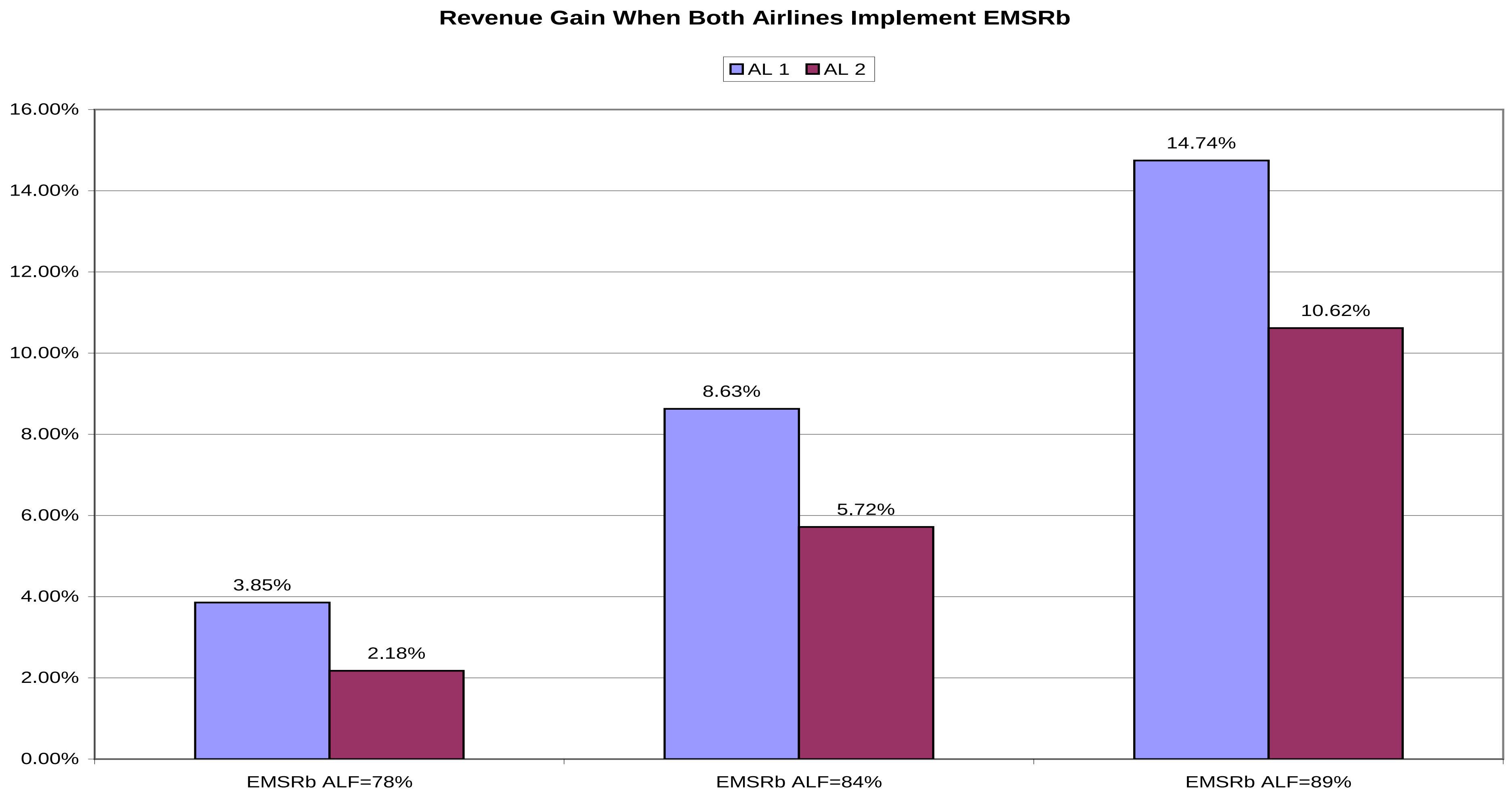
- **RM systems revise forecasts and re-optimize booking limits at numerous "checkpoints":**
  - Monitor actual bookings vs. previously forecasted demand
  - Re-forecast demand and re-optimize at fixed checkpoints or when unexpected booking activity occurs
  - Can mean substantial changes in fare class 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

Revision of Forecasts and Limits as Bookings Accepted

CABIN CAPACITY =		**135**				
AVAILABLE SEATS =		**63**				
BOOKING	**AVERAGE**	**SEATS**	**FORECAST DEMAND**		**JOINT**	**BOOKING**
CLASS	**FARE**	**BOOKED**	**MEAN**	**SIGMA**	**PROTECT**	**LIMIT**
Y	$ 670	2	10	5	5	**63**
M	$ 550	4	13	7	19	**58**
B	$ 420	5	5	2	27	**44**
V	$ 310	12	10	5	40	**36**
Q	$ 220	17	20	6	63	**23**
L	$ 140	32	15	4		**0**
	SUM	**72**	**73**			

Higher than expected Q bookings close L class

Leg-Based RM Benefits Increase with Average Load Factor



Flight Overbooking

- **Determine maximum number of bookings to accept for a given physical capacity.**
- **Minimize total costs of <u>denied boardings</u> and <u>spoilage</u> (lost revenue).**
- **U.S. domestic no-show rates can reach 15-20 percent of final pre-departure bookings:**
  - On peak holiday days, when high no-shows are least desirable
  - Average no-show rates have dropped, to about 10% with more fare penalties and better efforts by airlines to firm up bookings
- **Effective overbooking can generate as much revenue gain as fare class seat allocation.**

Overbooking Terminology

• Physical Capacity	CAP
• Authorized Capacity	AU
• Confirmed Bookings	BKD <= AU
• No-show rate	NSR
• Show-up rate	SUR
• Passengers Boarded	PAX
• Denied Boardings	DB
• Spoilage	SP

Deterministic Overbooking Model

- **Based on estimate of mean NSR from recent history:**
  - Assume that BKD=AU (“worst case” scenario)
  - Find AU such that AU - NSR*AU = CAP
  - Or, AU = CAP/(1-NSR)

- **For CAP=100 and NSR=0.20, then:**

  AU = 100/(1-.20) = 125

- **How would this model perform in the real world, where NSR is not known with certainty?**

Probabilistic/Risk Model

- **Incorporates uncertainty about NSR for future flight:**
  - Standard deviation of NSR from history, STD
- **Find AU that will keep DB=0, assuming BKD=AU, with a 95% level of confidence:**
  - Assume a probability (Gaussian) distribution of no-show rates
- **Optimal AU given CAP, SUR, STD with objective of DB=0 with 95% confidence is:**

$$AU = \frac{CAP}{SUR + 1.645\ STD} = \frac{CAP}{1 - NSR + 1.645\ STD}.$$

- **In our example, with STD= 0.05:**

AU = 100 / (1-0.20 + 1.645*0.05) = 113

Probabilistic Model Extensions

1. **Reduce level of confidence of exceeding DB limit:**
   - Z factor in denominator will decrease, causing increase in AU
2. **Increase DB tolerance to account for voluntary DB:**
   - Numerator becomes (CAP+ VOLDB), increases AU
3. **Include forecasted empty F or C cabin seats for upgrading:**
   - Numerator becomes (CAP+FEMPTY+CEMPTY), increases AU
   - Empty F+C could also be “overbooked”
4. **Deduct group bookings and overbook remaining capacity only:**
   - Firm groups much more likely to show up
   - Flights with firm groups should have lower AU

Cost-Based Overbooking Model

- **Find AU that minimizes :**

  [Cost of DB + Cost of SP]

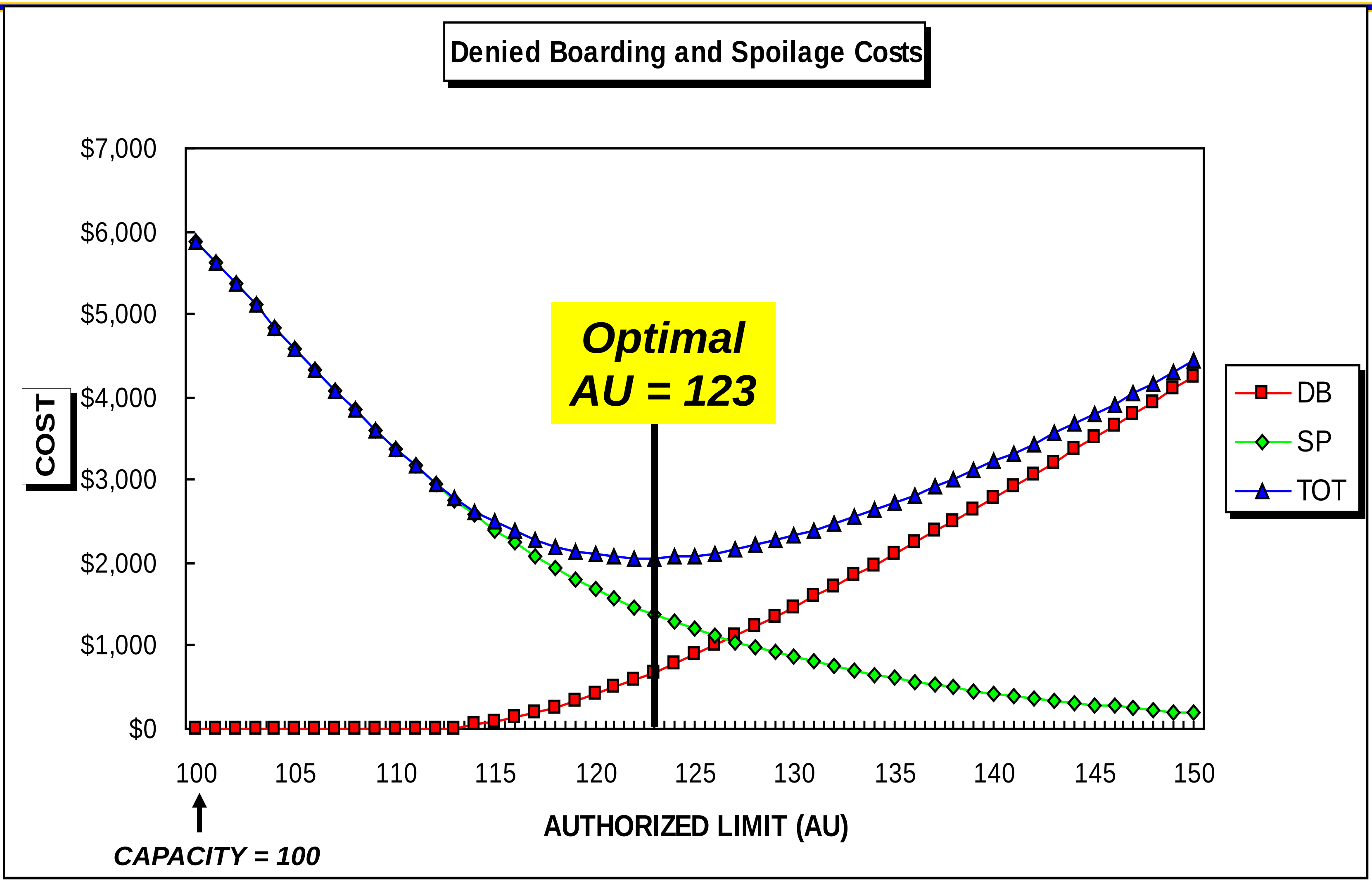
- **For any given AU:**

  Total Cost = $DB * E[DB] + $SP * E[SP]

  $DB and $SP= cost per DB and SP, respectively
  E[DB] = expected number of DBs, given AU
  E[SP] = expected number of SP seats, given AU

- **Mathematical search over range of AU values to find minimum total cost.**

Example: Cost-Based Overbooking Model



Costs of Denied Boardings and Spoilage

- **Denied Boarding Costs:**
  - Cash compensation for involuntary DB
  - Free travel vouchers for voluntary DB
  - Meal and hotel costs for displaced passengers
  - Space on other airlines
  - Cost of lost passenger goodwill

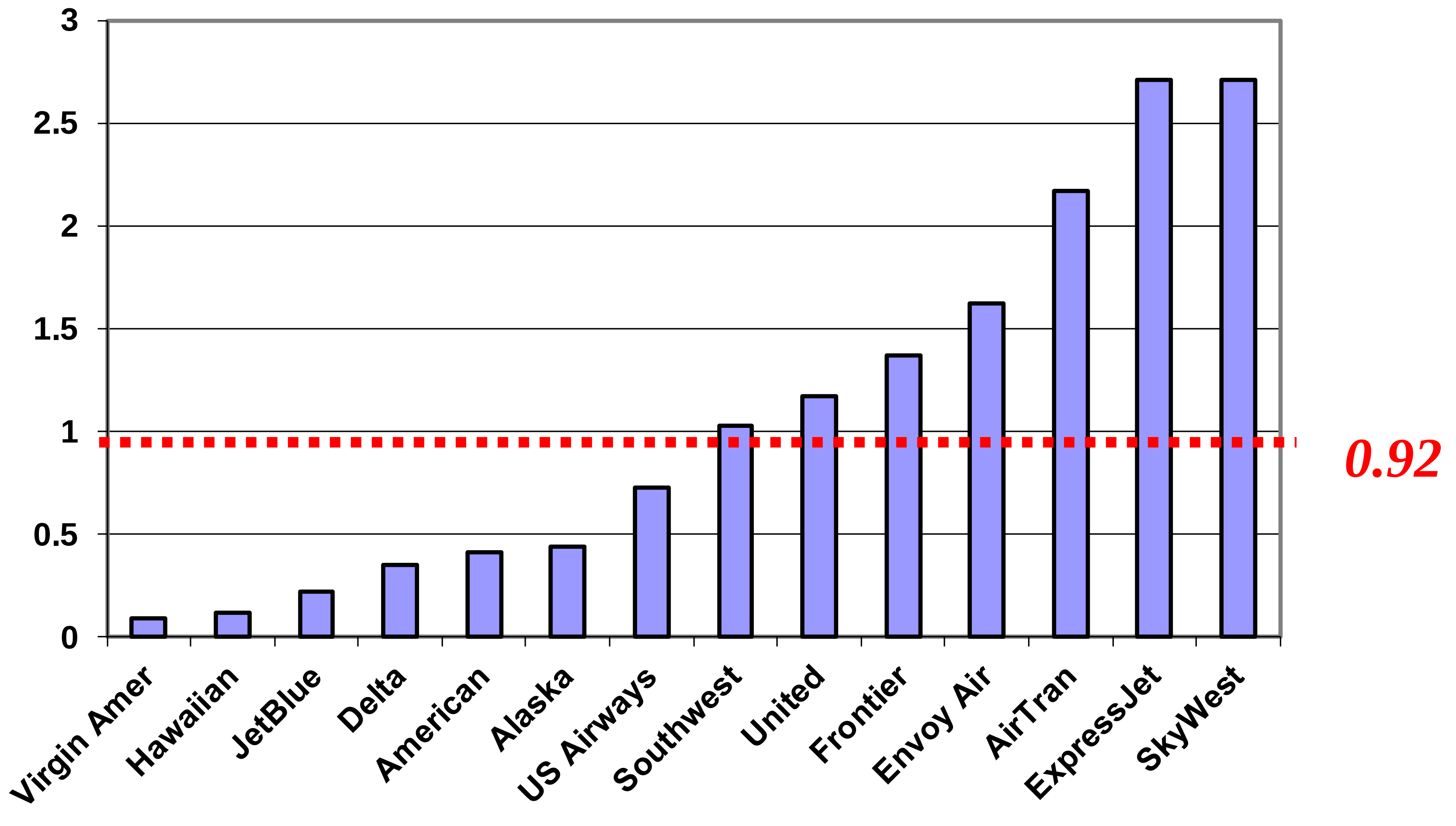
- **Spoilage Costs: Loss of revenue from seat that departed empty**
  - Average revenue per seat for leg?
  - Highest fare class revenue on leg (since closed flights lose late-booking passengers)?
  - Lowest fare class revenue on leg (since increased AU would have allowed another discount seat)?

Voluntary vs. Involuntary DBs

- **Comprehensive Voluntary DB Program:**
  - Requires training and cooperation of station crews
  - Identify potential volunteers at check-in
  - Offer as much "soft" compensation as needed to make the passenger happy

- **US airlines very successful in managing DBs:**
  - 2013 involuntary DB rate was 0.92 per 10,000
  - About 90% of DBs in U.S. are volunteers
  - Good treatment of volunteers generates goodwill

2014 US Involuntary DBs per 10,000



Source: www.bts.gov

Current State of RM Practice

- **Most of airlines (legacy and LCC) have implemented 3rd generation Leg RM systems:**
  - Revenue gains of 4 to 6 percent, at 75-80% average system load factors
  - Tactical matching of demand to supply – channel low-fare demand to empty flights
  - Maintain competitive pricing while controlling dilution

- **About 15-20 leading airlines are implementing 4th generation Network RM systems**
  - Further distinguish between local and connecting requests based on <u>network</u> revenue value