Demand, Load and Spill Analysis

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Lecture Outline

- **Terms and Definitions**
  - Demand, Load and Spill
  - Airline Demand Variability
- **Spill Analysis: Boeing Spill Model**
  - Estimating Spill Given Observed Load Factors
  - Use of Spill Tables
  - Impacts of Different Size Aircraft
- **Applications to Cabin Configuration**
- **Spill and Recapture Across Multiple Flights**
- **Impacts of RM on Spill**

Terms and Definitions

- **<u>DEMAND</u>: Total number of potential passengers wishing to book a seat on a given flight leg**
  - Total potential demand at current fare structure
- **<u>LOAD</u>: Number of passengers actually carried**
  - When demand is less than capacity, LOAD = DEMAND
- **<u>SPILL</u>: Number of potential passengers unable to book a seat due to insufficient capacity**
  - Also known as “rejected demand”
  - Equal to DEMAND minus LOAD

“Spill” vs. “Denied Boardings”

- **<u>SPILL</u> occurs when potential demand for a flight leg is greater than the physical capacity of the aircraft**
  - Spill can occur whether or not the airline is using overbooking methods
  - For spill analysis, typically assume no overbooking or “perfect” overbooking in which no-shows are predicted correctly
  - Spill occurs during the pre-departure booking process

- **DENIED BOARDINGS occur on overbooked flights when more passengers than capacity show up**
  - Denied boardings occur because the airline overbooked too aggressively, not because the aircraft was too small
  - DBs occur at the gate just before departure

Airline Demand Variability

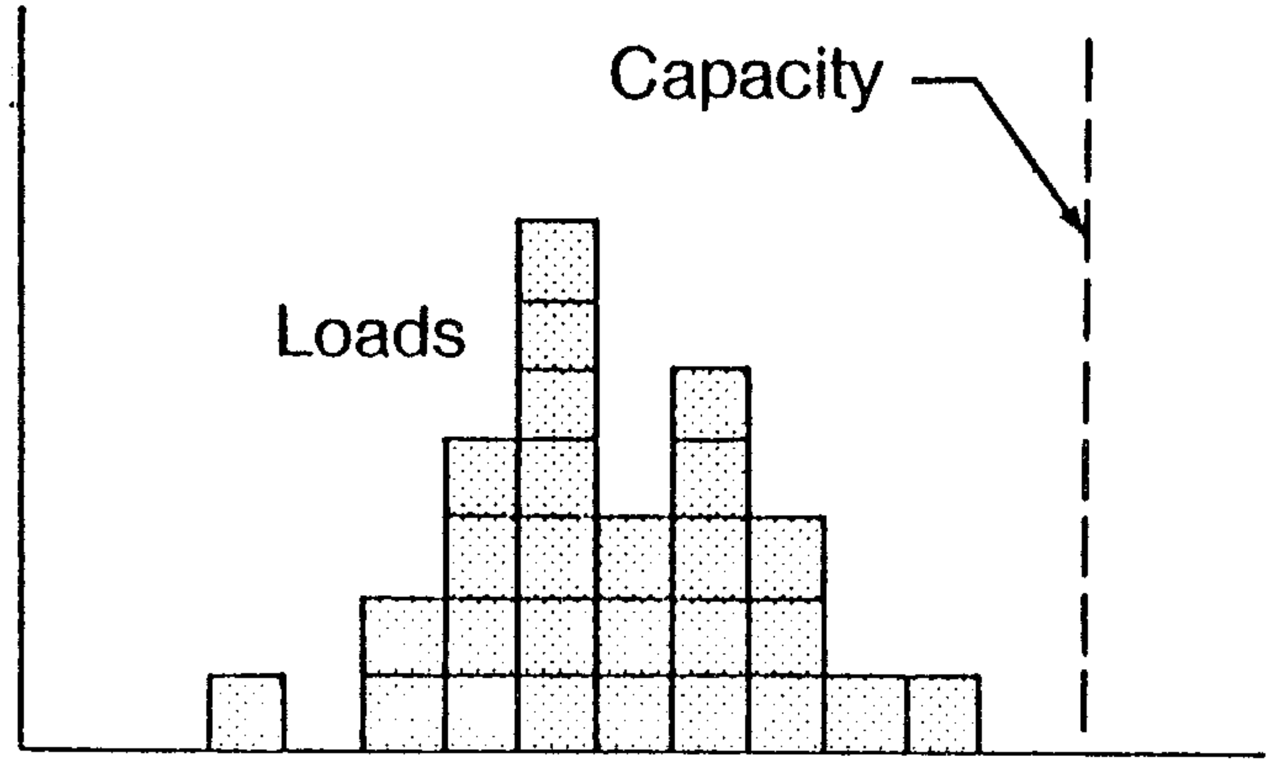
- **Total demand for a flight leg varies**
  - Cyclically: Season of year; day of week; time of day
  - Stochastically: Random fluctuations in demand
- **Total demand potential for a flight leg represented with a Gaussian distribution**
  - Mean and standard deviation over a schedule period
  - K-factor = coefficient of variation = sigma / mean
- **K-factor of total unconstrained demand**
  - Can vary by route, by schedule period
  - Higher for leisure markets and longer schedule periods
  - Typically assumed to range from 0.20 to 0.40
- **But, total unconstrained demand cannot be observed**
  - Unless aircraft capacity is always too large for demand

Example: Individual Flight Departures

DATE	LOAD	CAP	LF	SPILL?
01 APR	92	125	74%	NO
08 APR	125	125	100%	LIKELY
15 APR	108	125	86%	NO
22 APR	83	125	66%	NO
29 APR	123	125	98%	POSSIBLY

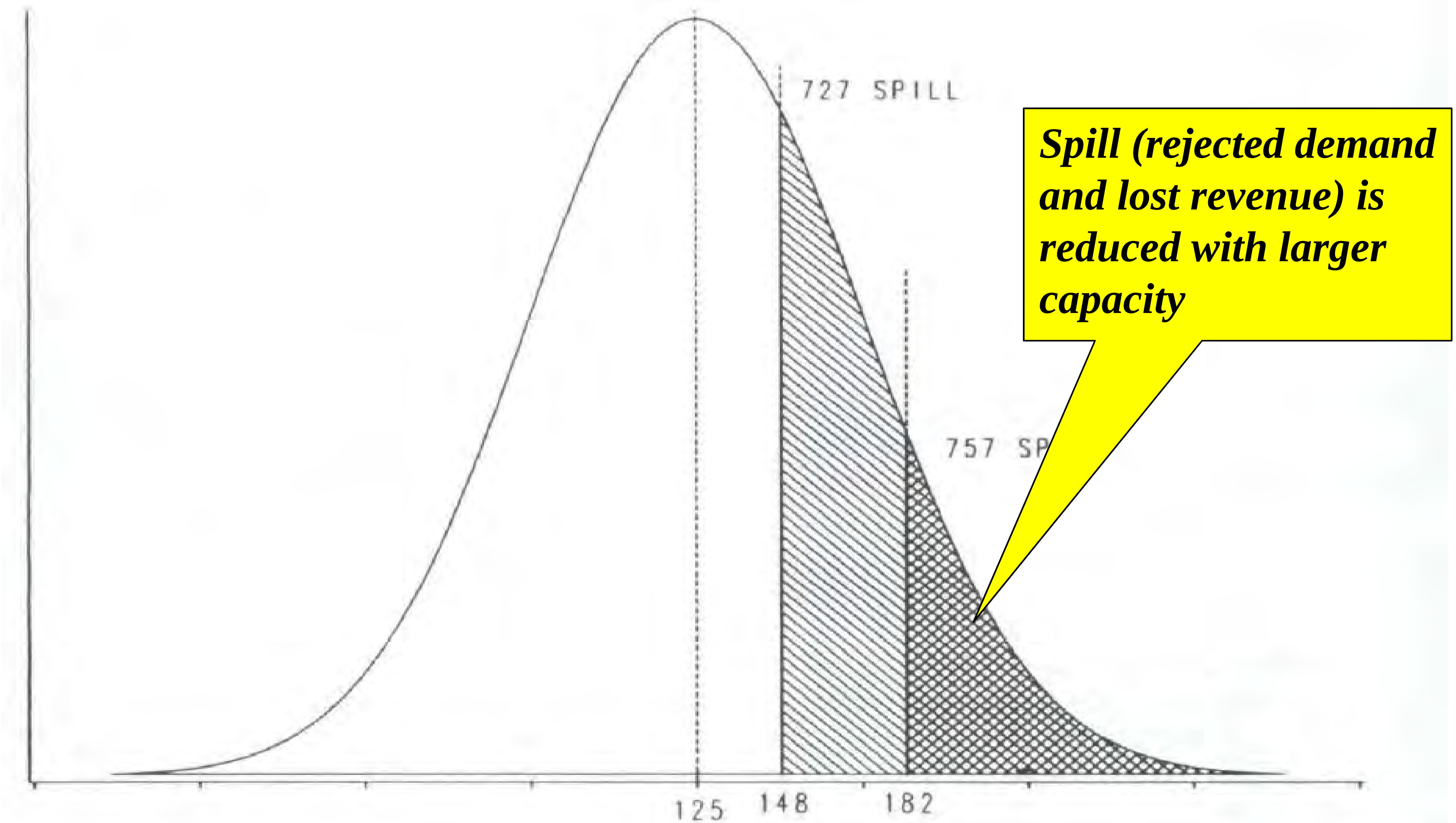
- **Sample of n=5 flight departures with ALF=85.0% given capacity 125 seats – spill occurred in 2/5 cases.**

Frequency Histogram of Flight Loads



Source: Boeing (1978)

Demand with Mean=125, Sigma=45



Spill Analysis: Boeing Spill Model

- **Objective: Estimate actual "unconstrained" demand for a sample of flights where spill has occurred.**
- **Observations: Sample of flight leg loads (constrained) over a representative time period:**
  - Perhaps adjusted for future seasonality and/or traffic growth
- **Assumptions:**
  - Unconstrained demand for a series of flight departures can be represented by a Gaussian distribution
  - We use observed Average Load Factor and an ASSUMED k-factor to estimate unconstrained demand
- **Boeing Spill Tables can be used to minimize calculations**

Example: Sample of Flight Departures

- **Mean load = 106.2 passengers (85.0% LF) with observed standard deviation= 18.6**
  - But, observed sigma constrained by capacity
  - Both mean and sigma are therefore smaller than actual demand
- **Assume K=0.35 for unconstrained demand**
  - Based on “market knowledge” and expected demand variability during schedule period under consideration
- **Spill Table (K=0.35) shows relationships between**
  - AVERAGE LOAD FACTOR = Mean Load/Capacity
  - DEMAND FACTOR = Mean Demand/Capacity
  - SPILL FACTOR = Mean Spill/Capacity
- **“Spill Rate” = Mean Spill / Mean Demand**
  - Historical target for spill rate is 5-10% or less

Spill Table for K=0.35

DF and SF given LOAD FACTOR

LF	DF	SF	LF	DF	SF
.700	.716	.016	.705	.722	.017
.710	.729	.019	.715	.735	.020
.720	.742	.022	.725	.749	.024
.730	.755	.025	.735	.762	.027
.740	.769	.029	.745	.776	.031
.750	.784	.034	.755	.791	.036
.760	.799	.039	.765	.806	.041
.770	.814	.044	.775	.822	.047
.780	.830	.050	.785	.839	.054
.790	.847	.057	.795	.856	.061
.800	.865	.065	.805	.874	.069
.810	.884	.074	.815	.894	.079
.820	.904	.084	.825	.914	.089
.830	.925	.095	.835	.936	.101
.840	.948	.108	.845	.960	.115
.850	.972	.122	.855	.985	.130
.860	.999	.139	.865	1.013	.148
.870	1.028	.158	.875	1.043	.168
.880	1.060	.180	.885	1.077	.192
.890	1.095	.205	.895	1.115	.220

Source: Boeing

- **Assuming underlying demand has K=0.35**
- **Then, 0.850 observed average load factor translates to 0.972 demand factor and 0.122 spill factor**
- **Load factor = demand factor – spill factor**

Spill Table Calculations

- **Given observed LF and assumed K=0.35**
  - DF = 0.972 from Table, and SF = 0.122
  - [Note that DF = LF + SF, always!]
- **We can now calculate the following estimates:**
  - Mean total demand = DF * Capacity = 0.972*125= 121.5
  - Std deviation of Demand = 0.35 * 121.5 = 42.5
  - Mean spill per departure = SF * Capacity = 0.122*125 = 15.3 [NOTE also: Mean Spill = Mean Demand – Mean Load]
  - Spill Rate = Mean Spill/Mean Demand = 15.3 / 121.5 = 12.6%

Impact of Larger Capacity (140 seats)

- **With estimated Mean Demand = 121.5 and Cap=140**
  - Demand Factor = 121.5/140 = 0.868
  - [Mean Demand does not change with a change in capacity!]
- **From Spill Table (K=0.35), with DF=0.868**
  - New average LF expected to be 0.802 (with some interpolation)
  - New mean load = 0.802 * 140 = 112.3 passengers, an increase of 6.1 passengers per departure
  - New average spill = 0.066*140 = 9.2 passengers, a decrease of 6.1 passengers per departure
  - New spill rate = 9.2/121.5 = 7.6%
- **Use of larger aircraft increases load, reduces spill, but decreases load factor. Demand does not change.**

Spill Table for K=0.35

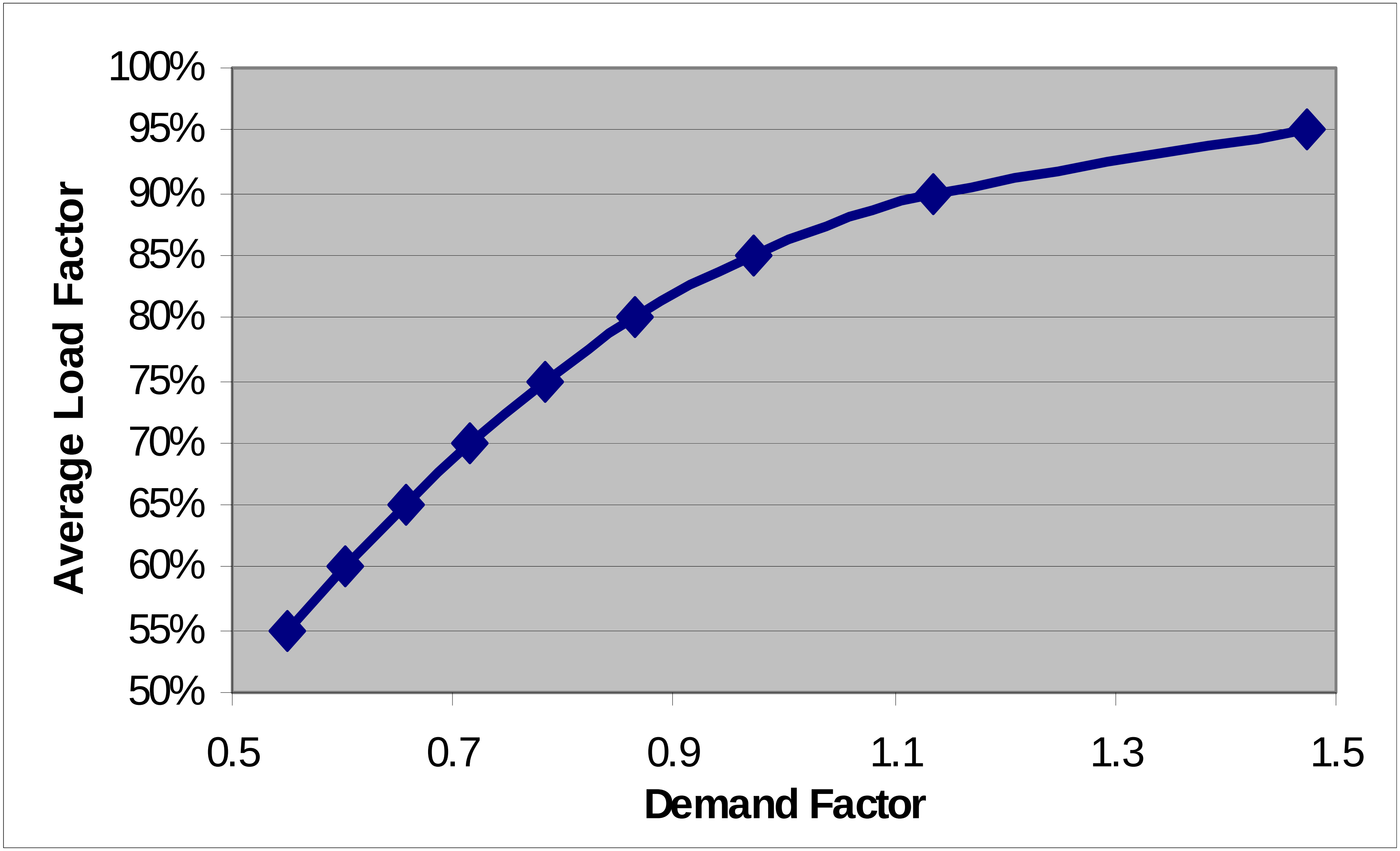
LF and SF given DEMAND FACTOR

DF	LF	SF	DF	LF	SF
.800	.761	.039	.805	.764	.041
.810	.767	.043	.815	.771	.044
.820	.774	.046	.825	.777	.048
.830	.780	.050	.835	.783	.052
.840	.786	.054	.845	.789	.056
.850	.792	.058	.855	.794	.061
.860	.797	.063	.865	.800	.065
.870	.803	.067	.875	.805	.070
.880	.808	.072	.885	.811	.074
.890	.813	.077	.895	.816	.079
.900	.818	.082	.905	.820	.085
.910	.823	.087	.915	.825	.090
.920	.828	.092	.925	.830	.095
.930	.832	.098	.935	.834	.101
.940	.837	.103	.945	.839	.106
.950	.841	.109	.955	.843	.112
.960	.845	.115	.965	.847	.118
.970	.849	.121	.975	.851	.124
.980	.853	.127	.985	.855	.130
.990	.857	.133	.995	.859	.136

- **Assuming underlying demand has K=0.35**
- **Then, 0.870 estimated demand factor translates to 0.803 average load factor and 0.067 spill factor**
- **Demand factor = load factor + spill factor**

Source: Boeing

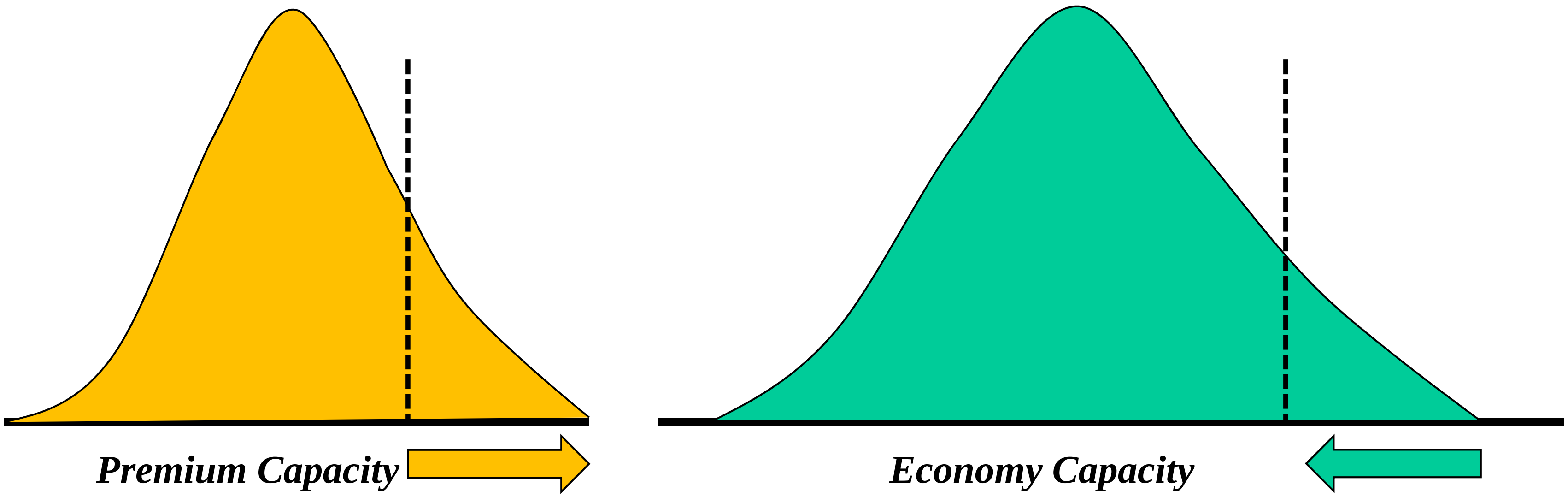
DF vs. LF for Demand (K=0.35)



Alternative Aircraft Capacities

- **Should the airline operate a 140-seat aircraft to serve this demand distribution?**
- **Increasing capacity by 15 seats expected to increase average load per departure by 6.1 passengers**
  - Increase in revenue per flight = 6.1 passengers * average fare
- **But, changing this fleet assignment to a larger aircraft will increase operating costs as well**
  - Increase in operating costs = difference in cost/block-hour * number of block-hours for flight leg in question

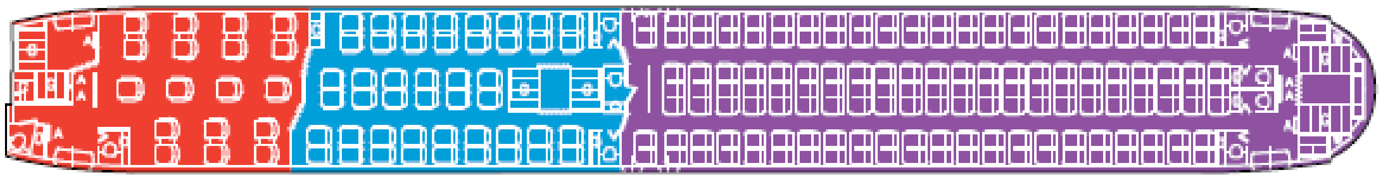
Applications to Cabin Configuration



- **Additional seats in Premium Class reduce premium spill and increase revenues; but reduction in Economy seats increases economy spill and reduces economy revenue**

- **Spill model can be used to estimate the trade-off in premium revenue gain vs. economy revenue loss**

Cabin Configurations for B767-300

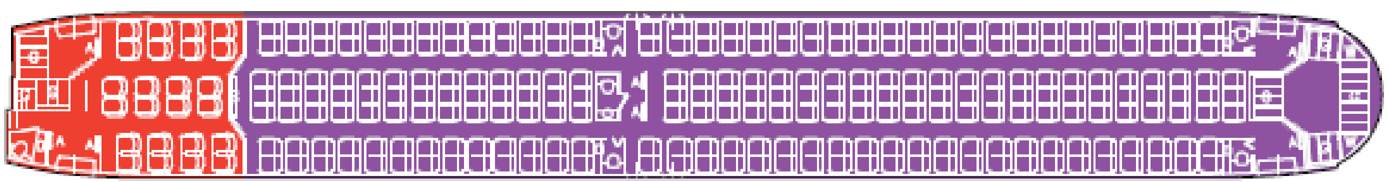


18 first
60-in pitch

46 business
38-in pitch

154 premium
32-in pitch

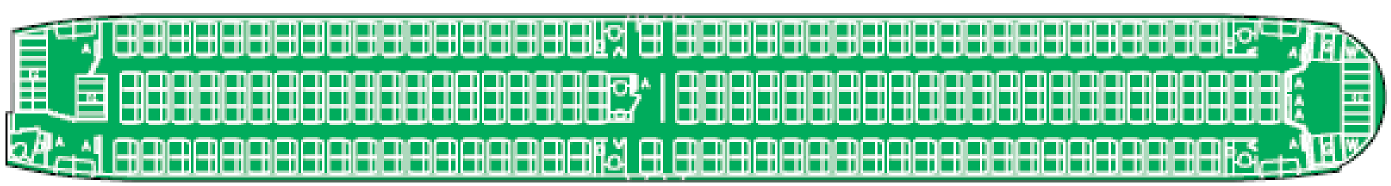
218 passengers



24 first
38-in pitch

245 premium
32-in pitch

269 passengers

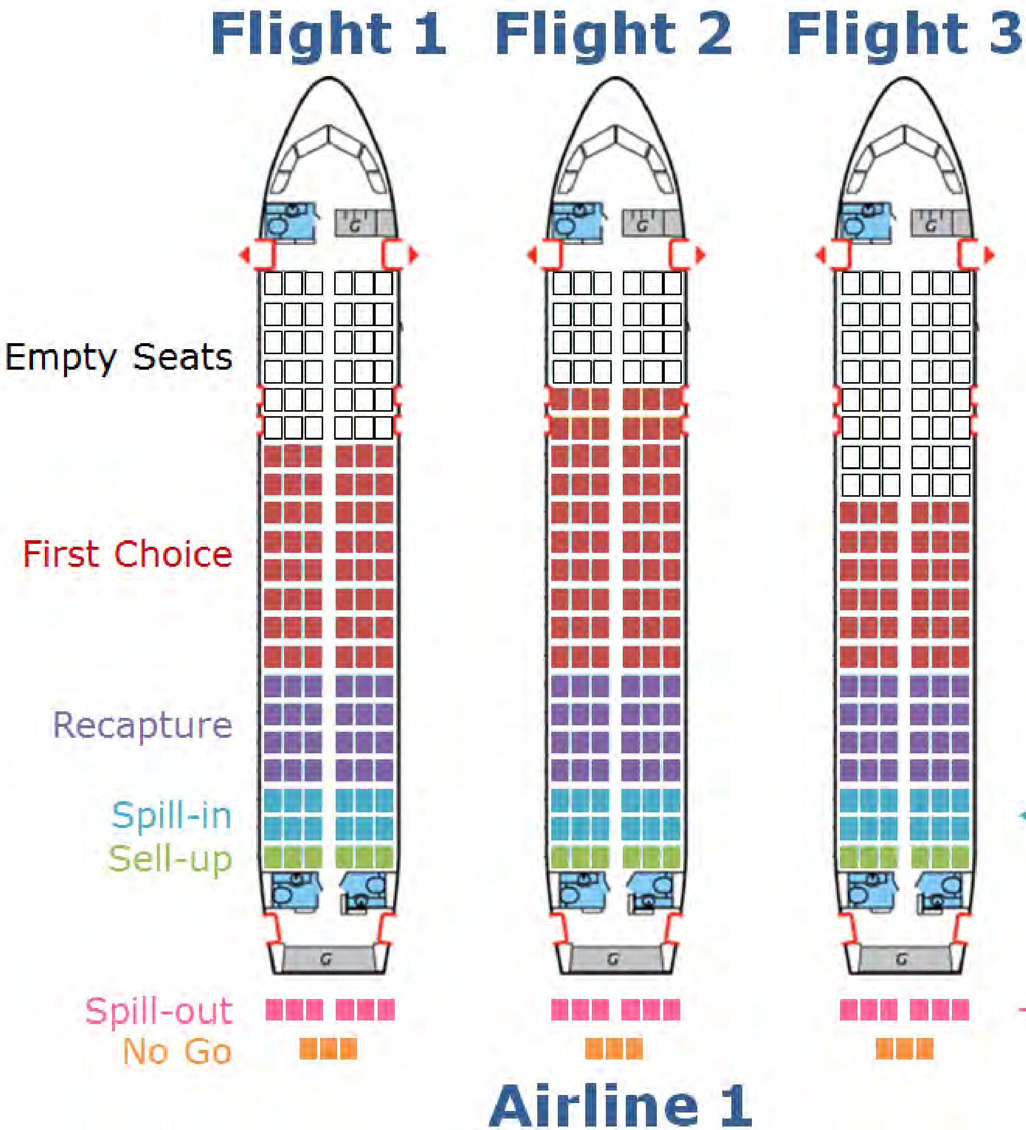


32-in pitch

286 passengers

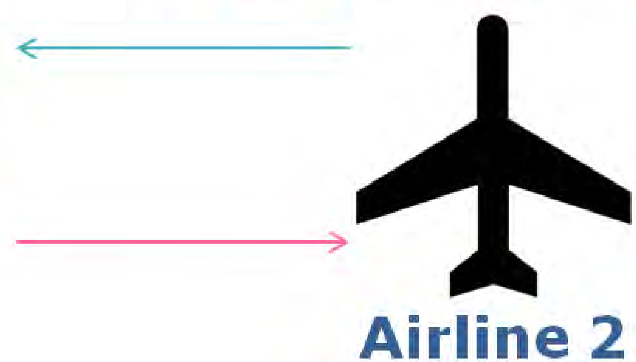
Source: Boeing Commercial Airplanes

Spill and Recapture Across Multiple Flights



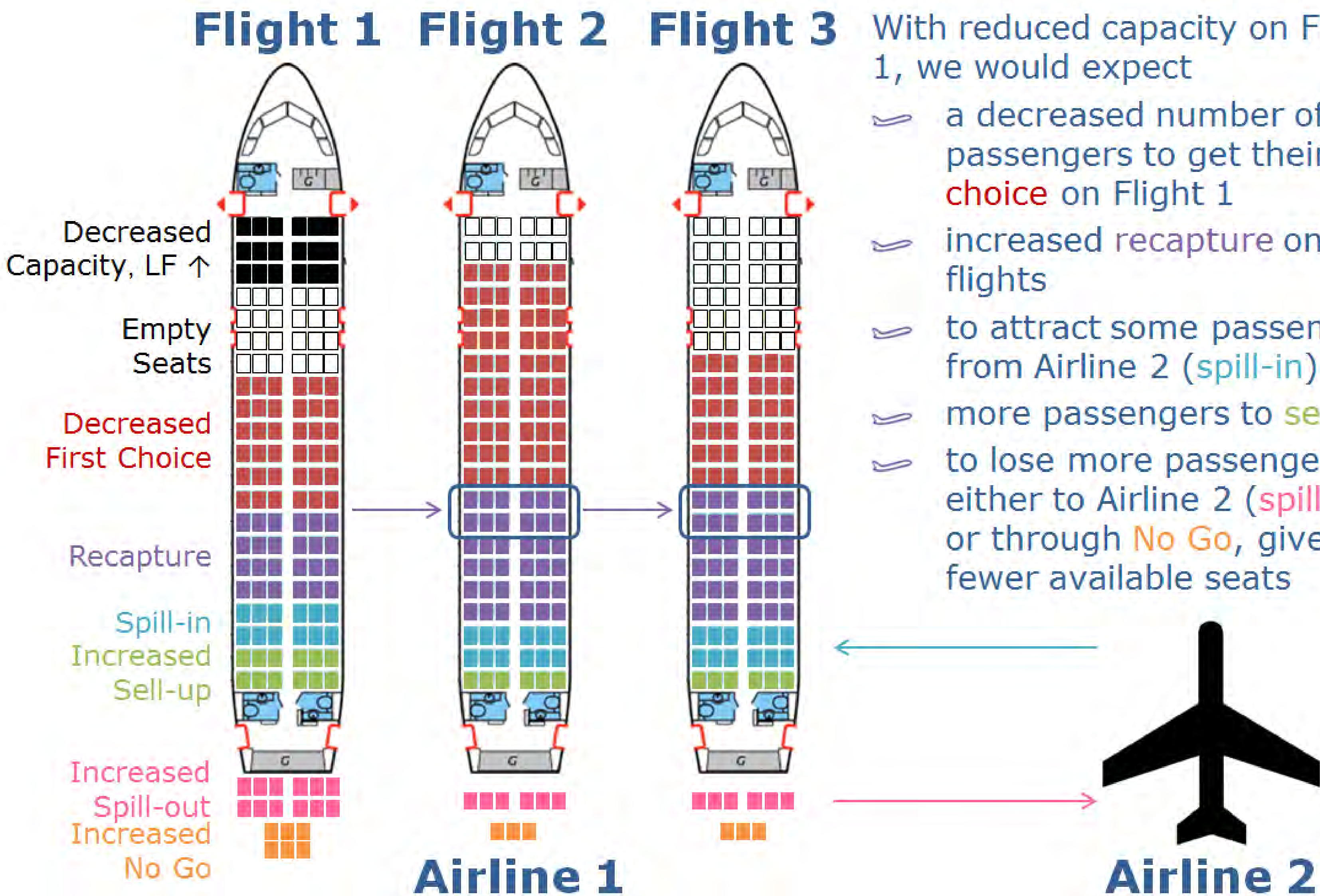
Airline 1's flights

- have a certain number of passengers getting their first choice on their desired flight
- have some number getting recaptured on other flights
- attract some passengers from Airline 2 (spill-in)
- have some passengers sell-up to get on their desired flight
- lose some number of passengers either to Airline 2 (spill-out) or through No Go



Source: Abramovich (2013)

Reduced Flight 1 Capacity

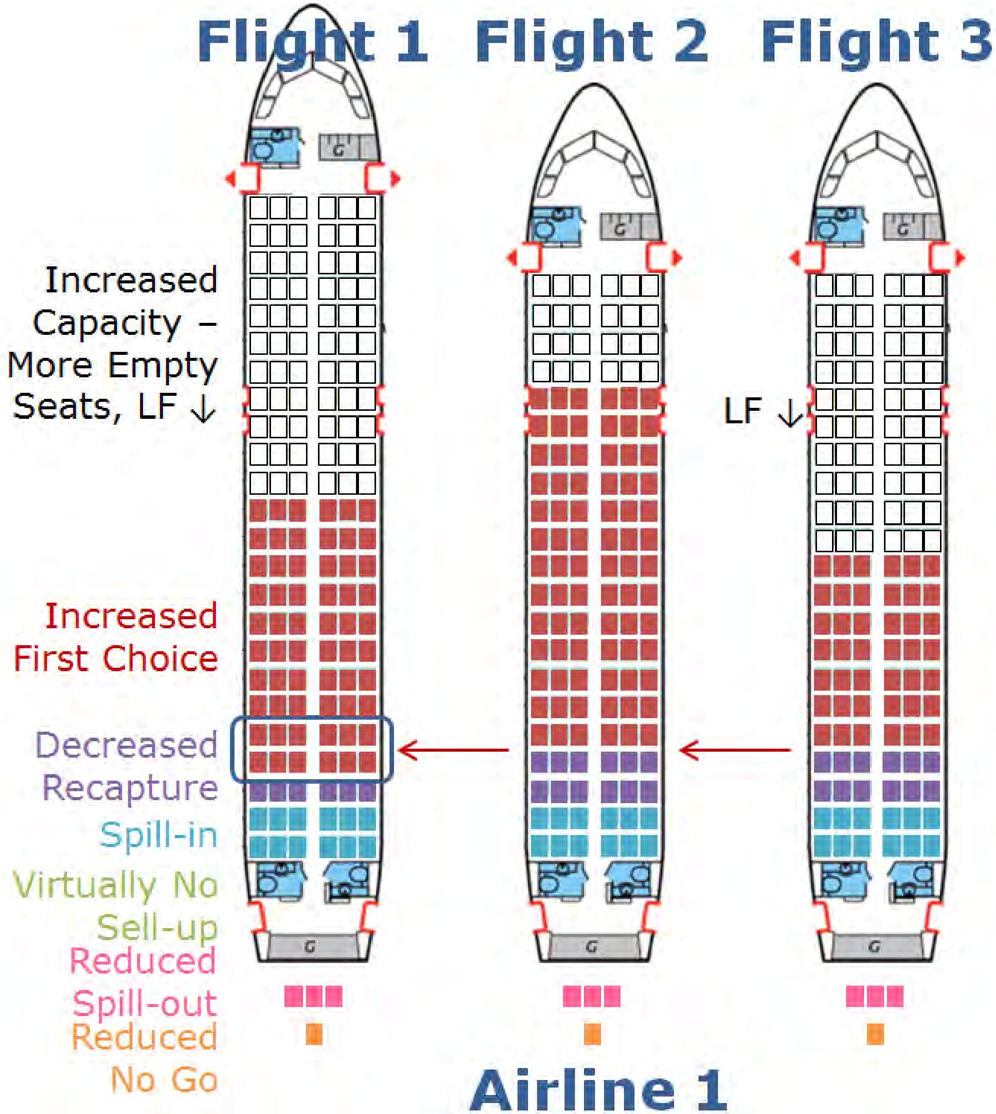


With reduced capacity on Flight 1, we would expect

- a decreased number of passengers to get their first choice on Flight 1
- increased recapture on other flights
- to attract some passengers from Airline 2 (spill-in)
- more passengers to sell-up
- to lose more passengers either to Airline 2 (spill-out) or through No Go, given fewer available seats

Source: Abramovich (2013)

Increase Flight 1 Capacity



With increased capacity on Flight 1, we would expect

- low LFs on Flight 1 and some changes in LFs on other flights
- an increased number of passengers to get their first choice on Flight 1
- decreased recapture on all flights as more passengers get their first choices
- to attract some passengers from Airline 2 (spill-in)
- virtually no sell-up due to the largely increased capacity
- to lose fewer passengers either to Airline 2 (spill-out) or through No Go, given far more available seats

Source: Abramovich (2013)

RM Systems Reject Demand

- **Revenue management system generates booking limits for each class to maximize revenue**
  - Protect seats for high fare passengers, reject low-fare bookings when demand factor is high

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**			

Source: Abramovich (2013)

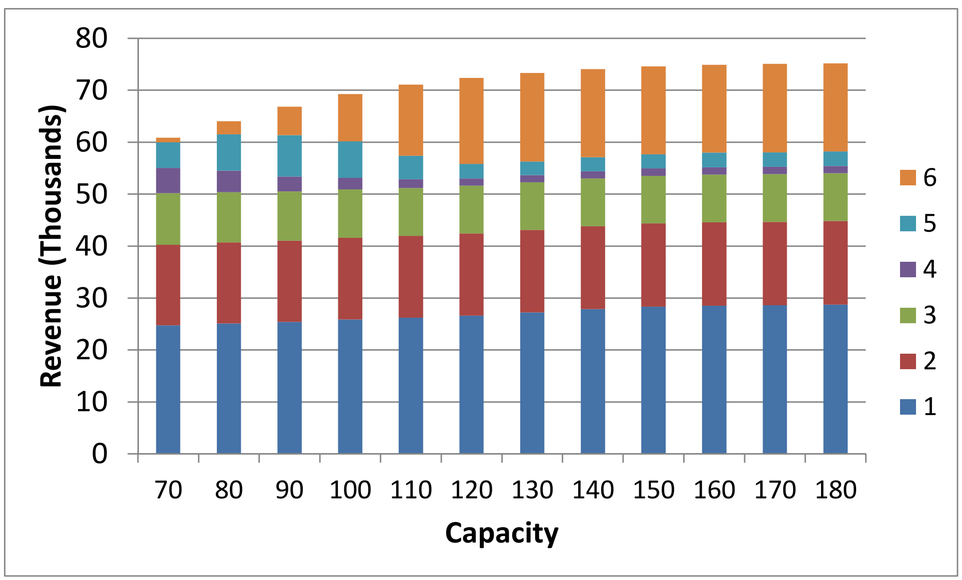
Impacts of RM on Marginal Revenue

- **Marginal revenue per additional seat decreases with increasing capacity.**

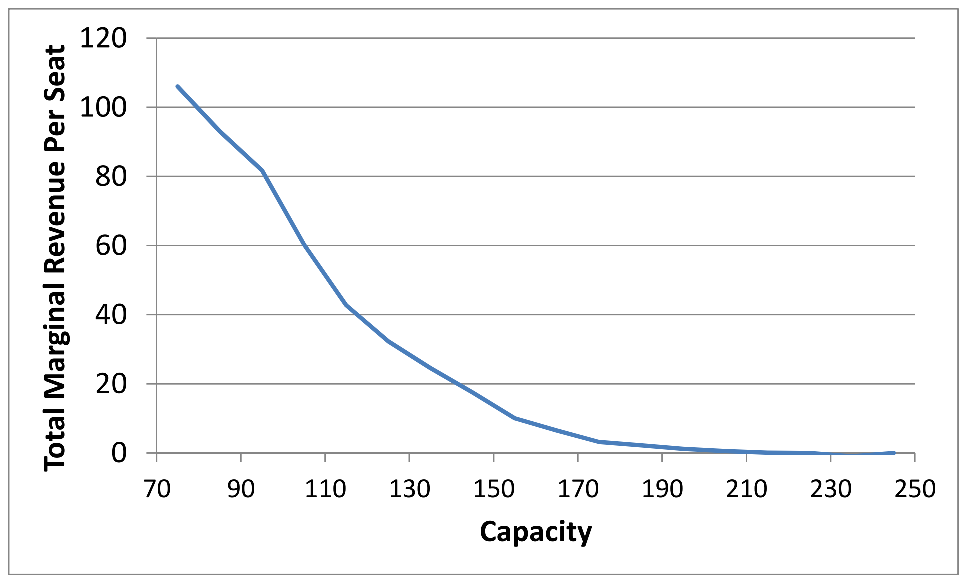
- **Most additional bookings are in lower classes.**

Standard Leg RM

Fare Class Mix



Marginal Revenue



Source: Abramovich (2013)