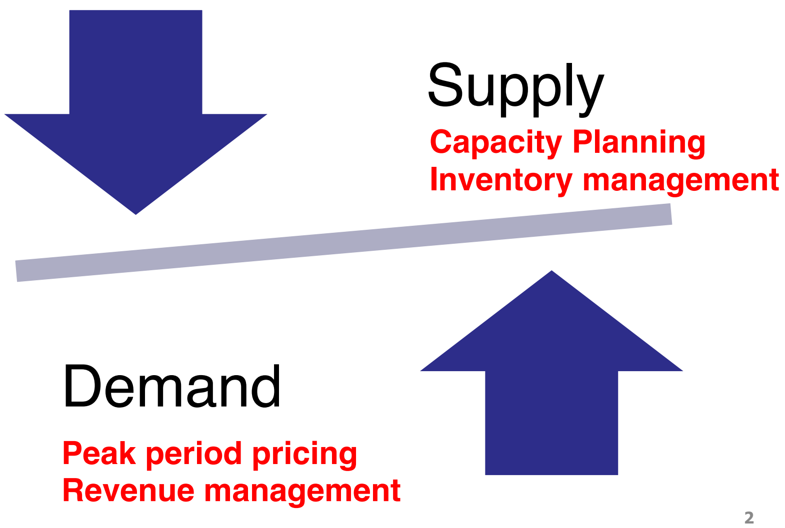
UCL
SCHOOL OF
MANAGEMENT

MSIN0095: Operations Analytics

Class 1-4: Process Analysis
Class 5,7: Waiting Time Analysis
Class 6: Inventory Management – Newsvendor Model
Class 8: Inventory Management – Newsvendor, Periodic Review
Class 9: Inventory Management – EOQ
Class 10: Inventory Management – Amazon Distribution Strategy
Class 11: Supply Chain Management I: Beer Game
Class 12: Supply Chain Management II
Class 13: Supply Chain Management III: Strategic Sourcing, Sustainable Supply Chains
Class 14: Demand Forecasting I
Class 15: Demand Forecasting II – Caesars Entertainment

Class 16-17: Revenue Management I

Matching supply with demand

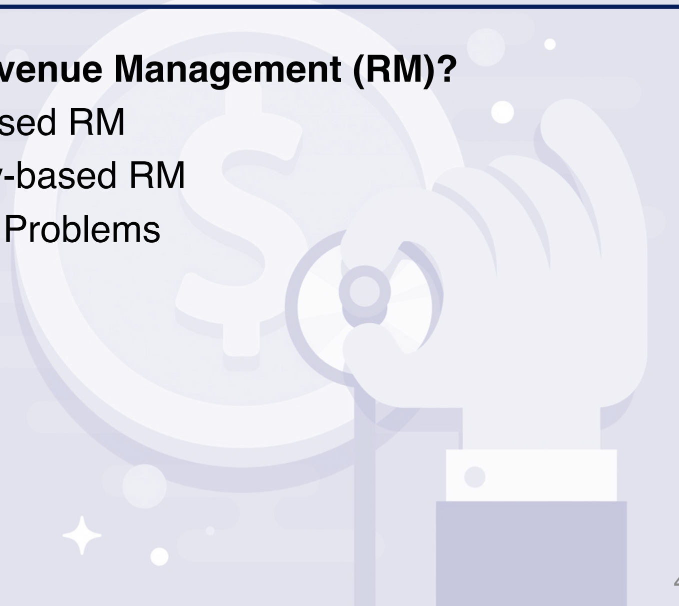


Willingness to pay model

- Find demand function from customer's willingness-to-pay
  - d(p) = number of customers with WTP > p
- If we find a continuous demand function
  - d(p) = a – b*p
  - Revenue = p * d(p)
  - Optimal price = a / (2b)

Learning Objectives

- **Why Revenue Management (RM)?**
- Price-based RM
- Capacity-based RM
- Practice Problems



Why Revenue Management?

- A typical airline
  - Operates with 73% of its seats filled
  - Needs to fill 70% of its seats to break even
- On a 100-seat aircraft, the difference between making and losing money is just a handful of passengers.

5

Why Revenue Management?

(in millions, except per share data)	Three Months Ended September 30, 2016	Three Months Ended September 30, 2015	Nine Months Ended September 30, 2016	Nine Months Ended September 30, 2015
Operating Revenue:				
Passenger:				
Mainline	$ 7,615	$ 8,059	$ 21,530	$ 22,195
Regional carriers	1,456	1,536	4,273	4,462
Total passenger revenue	9,071	9,595	25,803	26,657
Cargo	167	196	494	620
Other	1,245	1,316	3,884	3,925
Total operating revenue	10,483	11,107	30,181	31,202
Operating Expense:				
Salaries and related costs	2,463	2,276	7,165	6,563
Aircraft fuel and related taxes	1,422	1,819	3,877	5,111
Regional carriers expense	1,119	1,073	3,221	3,223
Contracted services	520	477	1,480	1,375
Depreciation and amortization	474	466	1,430	1,384
Aircraft maintenance materials and outside repairs	462	479	1,357	1,430
Passenger commissions and other selling expenses	466	463	1,291	1,270
Landing fees and other rents	399	403	1,123	1,164
Profit sharing	326	563	922	1,110
Passenger service	264	247	674	664
Aircraft rent	72	63	204	183
Other	527	565	1,505	1,640
Total operating expense	8,514	8,894	24,249	25,117
Operating Income	1,969	2,213	5,932	6,085

Why Revenue Management?

DELTA

	1% ↑ Revenue	3% ↑ Revenue	7% ↑ Revenue
10,483 M	10,588 M	10,797 M	11,217 M
- 8,514 M	- 8,514 M	- 8,514 M	- 8,514 M
1,969 M	2,074 M	2,283 M	2,703 M
	5% ↑ Profit	16% ↑ Profit	37% ↑ Profit

- A 3 to 7 percent increase in revenue can easily generate 15 to 50 percent increase in profit.

7

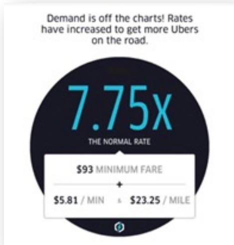
What is Revenue Management?

- *Revenue Management*, also called *Yield Management*, was first developed by American Airlines in 1980s.
- Maximize revenue earned from fixed and perishable resources
- More applications…
  - sports leagues, concert planners, retailers

AA AVIS Hilton ZARA

Evolution of Revenue Management

- Capacity-based RM
  - Optimally allocating capacity of a resource to different classes of demand
  - Booking limits and Overbooking
- Price-based RM
  - Controlling price and modeling demand as a price-dependent process
  - Markdown pricing in retail
  - Surge pricing by Uber
    - dynamic pricing on both demand and supply side



Learning Objectives

- Why Revenue Management (RM)?
- **Price-based RM**
- Capacity-based RM
- Practice Problems

Willingness-To-Pay

- Segment customers by their <u>willingness-to-pay</u>

- **Willingness-to-pay (WTP)** : the maximum cost a customer is willing to incur to obtain a unit of product or service.

- Different customers have different willingness-to-pay, in other words, price sensitivity.

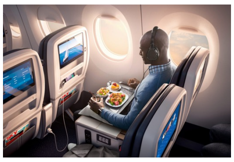
Willingness-To-Pay

- What affects willingness-to-pay?
  - **Customer characteristics** such as age, income, gender
  - **Product/service characteristics** such as quality, brand
  - **Availability of substitute options** (by the same provider or by competitors)

- Price optimization
  - Single product
  - Multiple product

Single Product

- Willingness-to-pay for DTW to SFO

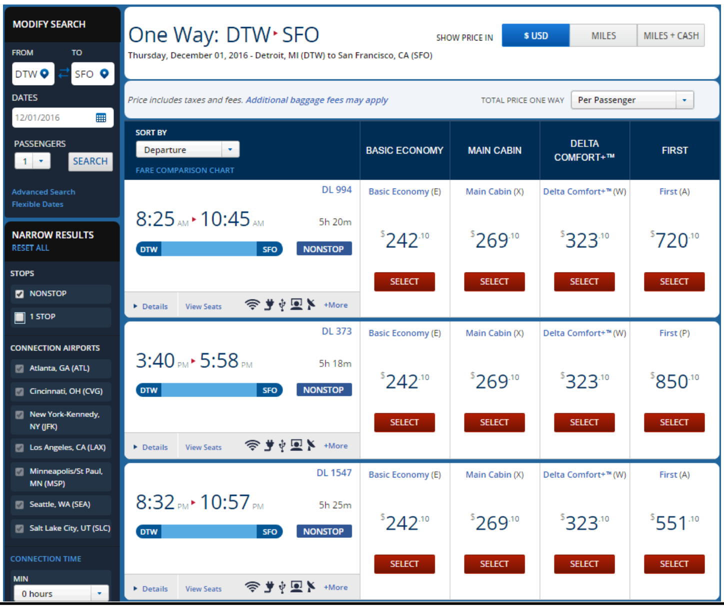


WTP	Frequencies
$800	3
$700	7
$600	12
$500	33
$400	22
$300	14
$200	9
Total	100

Price	Demand	Revenue
$800	3	$2,400
$700	10	$7,000
$600	22	$13,200
$500	55	$27,500
$400	77	$30,800
$300	91	$27,300
$200	100	$20,000

Revenue maximized when price is **$400**

Multiple Products: Consumer Choice Set



Multiple Products

- Consider that Delta operates <u>two flights</u> daily from DTW to SFO:
  - Morning flight @ 10am
  - Evening flight @ 6pm
- Consumers have <u>different willingness to pay</u> for each flight
- How much to charge for each flight in order to maximize total expected revenue

What Happens When Prices Change

Stay at Home

Fly in the morning

Fly in the night

- What happens when price of one product, say, the price of <u>evening flight</u> goes up?
  - # people who take evening flight? ↓
  - # people who take morning flight? ↑
  - # people who does not fly? ↑

Price Optimization over Consumer Choice Set

- Each option offers a **net utility** to each consumer
  - **Net utility = WTP – price**
  - Outside option net utility = 0
- A consumer chooses the option that gives him/her the highest net utility

17

Price Optimization over Consumer Choice Set

- Each option offers a net utility to each consumer
  - Net utility = WTP – price
  - Outside option net utility = 0
- A consumer choose the option that gives h her the highest net utility

What are the net utilities of each option?

	WTP	
Customer ID	10am	6pm
1	$200	$200
2	$200	$500
3	$300	$500
4	$300	$300
5	$300	$600
6	$300	$700
7	$300	$300
8	$300	$600
9	$400	$800
10	$400	$900

Price Optimization over Consumer Choice Set

- Tiebreaking rule
  - If highest net utility of AM/PM is zero, customer will choose to purchase
  - If both A est net utility, will choose either w

If 6pm flight is priced at $300, which option will Customer 1 choose?

	WT		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	($100)	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	$200	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	$200	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- Tiebreaking rule
  - If highest net utility of AM/PM is zero, customer will choose to purchase
  - If both A est net utility, will choose either w

If 6pm flight is priced at $300, which option will Customer 1 choose?

	WT		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	($100)	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	$200	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	$200	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- <u>Tiebreaking rule</u>
  - If highest net utility of AM/PM is zero, customer will choose to purchase.
  - If both AM and PM give highest net utility, will choose either wit bability.

What about
Customer 2?

	WTP		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	$200	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	$200	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- <u>Tiebreaking rule</u>
  - If highest net utility of AM/PM is zero, customer will choose to purchase.
  - If both AM and PM give highest net utility, will choose either wit bability.

What about
Customer 3?

	WTP		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	6pm	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	$200	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- Tiebreaking rule
  - If highest net utility of AM/PM is zero, customer will choose to purchase.
  - If both AM and PM give highest net utility, will choose either wit … ability.

What about Customer 4?

	WTP		Net Utility							
			Not fly	10am	6pm					
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	6pm	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	6pm	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- Tiebreaking rule
  - If highest net utility of AM/PM is zero, customer will choose to purchase.
  - If both AM and PM give highest net utility, will choose either with equal probability.

	WTP		Net Utility							
			Not fly	10am	6pm					
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	($200)	($300)	($400)	($500)	($600)
2	$200	$500	$0	($100)	6pm	$100	$0	($100)	($200)	($300)
3	$300	$500	$0	$0	6pm	$100	$0	($100)	($200)	($300)
4	$300	$300	$0	$0	am/pm	($100)	($200)	($300)	($400)	($500)
5	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
6	$300	$700	$0	$0	$400	$300	$200	$100	$0	($100)
7	$300	$300	$0	$0	$0	($100)	($200)	($300)	($400)	($500)
8	$300	$600	$0	$0	$300	$200	$100	$0	($100)	($200)
9	$400	$800	$0	$100	$500	$400	$300	$200	$100	$0
10	$400	$900	$0	$100	$600	$500	$400	$300	$200	$100

Price Optimization over Consumer Choice Set

- <u>Tiebreaking rule</u>
  - If highest net utility of AM/PM is zero, customer will choose to purchase.
  - If both AM and PM give highest net utility, will choose either with equal probability.

	WTP		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	not fly	not fly	not fly	not fly	not fly
2	$200	$500	$0	($100)	6pm	6pm	6pm	not fly	not fly	not fly
3	$300	$500	$0	$0	6pm	6pm	am/pm	10am	10am	10am
4	$300	$300	$0	$0	am/pm	10am	10am	10am	10am	10am
5	$300	$600	$0	$0	6pm	6pm	6pm	am/pm	10am	10am
6	$300	$700	$0	$0	6pm	6pm	6pm	6pm	am/pm	10am
7	$300	$300	$0	$0	am/pm	10am	10am	10am	10am	10am
8	$300	$600	$0	$0	6pm	6pm	6pm	am/pm	10am	10am
9	$400	$800	$0	$100	6pm	6pm	6pm	6pm	6pm	10am
10	$400	$900	$0	$100	6pm	6pm	6pm	6pm	6pm	am/pm

25

Price Optimization over Consumer Choice Set

- Which price optimizes total revenue?

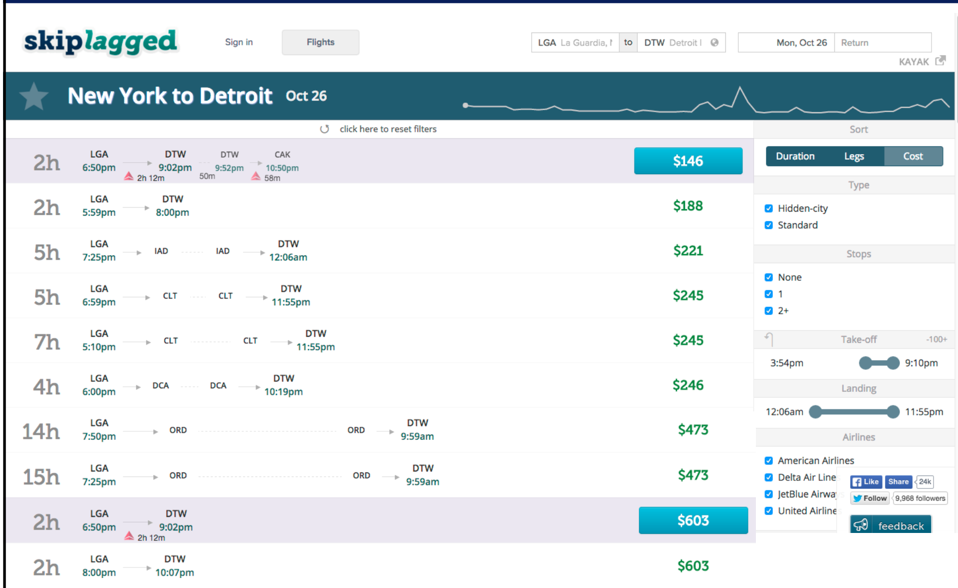
	WTP		Net Utility								
			Not fly	10am	6pm						
Customer ID	10am	6pm		Price = $300	$300	$400	$500	$600	$700	$800
1	$200	$200	$0	($100)	not fly	not fly	not fly	not fly	not fly	not fly
2	$200	$500	$0	($100)	6pm	6pm	6pm	not fly	not fly	not fly
3	$300	$500	$0	$0	6pm	6pm	am/pm	10am	10am	10am
4	$300	$300	$0	$0	am/pm	10am	10am	10am	10am	10am
5	$300	$600	$0	$0	6pm	6pm	6pm	am/pm	10am	10am
6	$300	$700	$0	$0	6pm	6pm	6pm	6pm	am/pm	10am
7	$300	$300	$0	$0	am/pm	10am	10am	10am	10am	10am
8	$300	$600	$0	$0	6pm	6pm	6pm	am/pm	10am	10am
			$0	$100	6pm	6pm	6pm	6pm	6pm	am/pm
			$0	$100	6pm	6pm	6pm	6pm	6pm	6pm

Charging **$500** for the 6pm flight maximizes total revenue!

	$300
Demand @ 10am	1
Revenue @ 10am	$300
Demand @ 6pm	8
Revenue @ 6pm	$2,400
Total Demand	9
Total Revenue	$2,700

26

Ice breaker: Hidden city flights



27

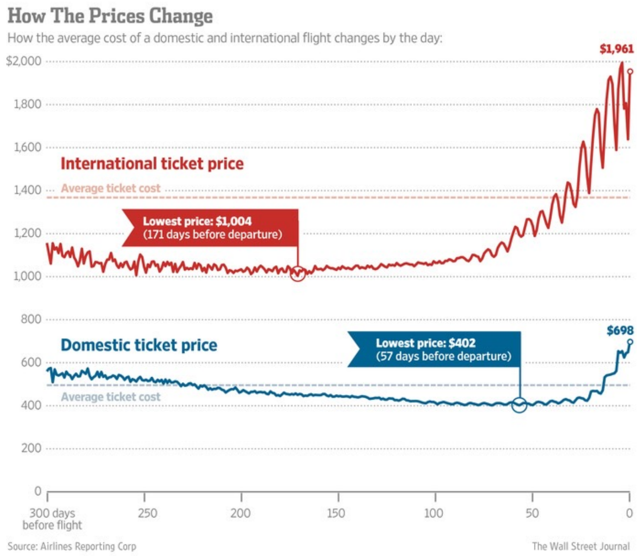
Learning Objectives

- Why Revenue Management (RM)?
- Price-based RM
- **Capacity-based RM**
- Practice Problems

28

28

Why Prices Change Over Time?



29

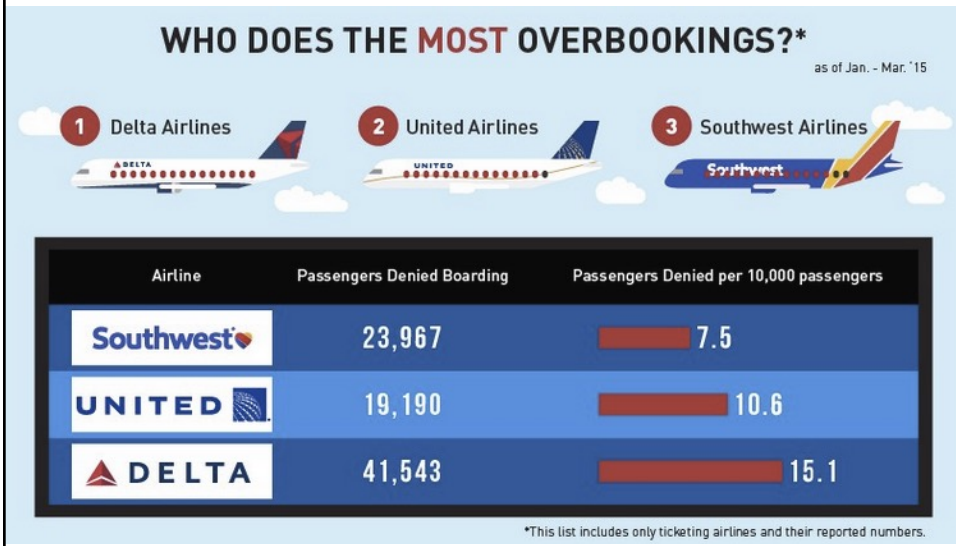
Protection Levels and Booking Limits

- Booking limit is the maximum capacity to be sold at the lower price
- You manage a hotel with 200 rooms in London. The football game is coming up. Sports fans either book a room in advance or wait until the last minute.
  - Advance booking: Bargain rate $200/night
  - Late booking: Premium rate $500/night
- <u>Demand is ample</u> – you can easily sell out all rooms offered at the bargain rate
  - How many rooms should be reserved for customers arriving late **(protection level)**?
    - Newsvendor logic

Room Reservation and Newsvendor

Newsvendor Problem	Room Reservation
Newspapers are "perishable"	Hotel rooms are "perishable"
Random newspaper demand	Random last-minute demand
Decide how many newspapers to purchase	Decide how many rooms to reserve for last-minute customers (protection level)
If stock too few newspapers, miss potential sales	If reserve too few rooms, miss potential premium customers
If stock too many newspapers, money wasted on unsold newspapers	If reserve too many rooms, revenue lost on empty rooms

Overbooking is a common industry practice



Airline	Passengers Denied Boarding	Passengers Denied per 10,000 passengers
Southwest	23,967	7.5
UNITED	19,190	10.6
DELTA	41,543	15.1

Overbooking

- You can easily get 200 reservations and fill up your hotel/flight
- Some people with reservations <u>may not show up</u>
- Should you take exactly 200 reservations or more than 200?
- How many more?
  - Newsvendor logic
  - Flight ticket is \$200 each
  - It costs \$300 to compensate the unboarded customer

Overbooking and Newsvendor

Newsvendor Problem	Overbooking
Newspapers are "perishable"	Overbooks are "perishable"
Random newspaper demand	Random no-shows
Decide how many newspapers to purchase	Decide how many overbooks
If stock too few newspapers, miss potential sales	If too few overbooks, miss potential sales
If stock too many newspapers, money wasted on unsold newspapers	If too many overbooks, incur loss of good-will

Implementation of Revenue Management

- Demand forecasting
  - Demand forecasts are necessary inputs to protection levels and overbooking quantities
- Dynamic decisions
  - Forecasts change frequently; so should protection levels and overbooking quantities
- Effectively segmenting customers
  - **Fare fences**: Let customers segment themselves by making the cheap product undesirable for premium customers. Examples: 21/14/7-day in advance booking requirement, Saturday night stay, (non)refundable fare
- Multiple fare classes
  - More than two fares, and change frequently