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Revenue Management in the US Airline Industry

A Review of Development and Some Bumps Along the Road

Barry C. Smith

October 31, 2006

Agenda

- **Revenue Management and Airline Planning**
- **Airline History**
- **RM Development**
  - Overbooking
  - Discount Allocations
  - O&D RM
  - Channel RM
  - Customer-based RM
- **RM in the Current Airline Environment**
- **Future Directions**
- **Final Thoughts**

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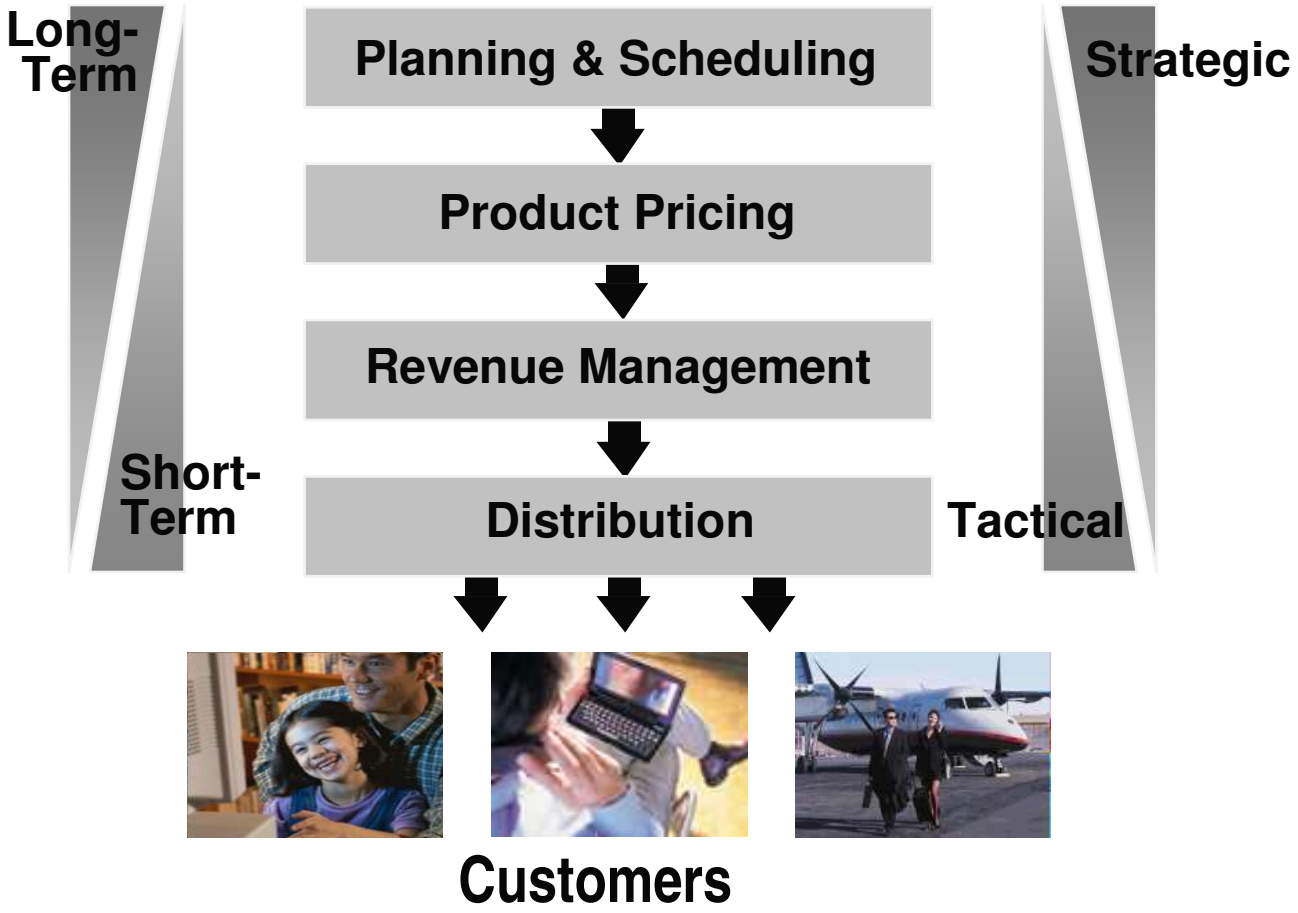
Revenue Management and Airline Planning

Airline Planning & Marketing Flow



Airline RM Problem: Big, Complex, Dynamic

- **Revenue Management increases profit by helping airlines match supply and demand**
- **Typical major carrier:**
  - 3000 flights per day
  - 10,000 markets
  - 4,000,000 fares
  - 100,000 fare changes per day
  - 330 day control horizon
  - $10 billion annual revenue
- **Annual RM benefits are approximately $500 million**

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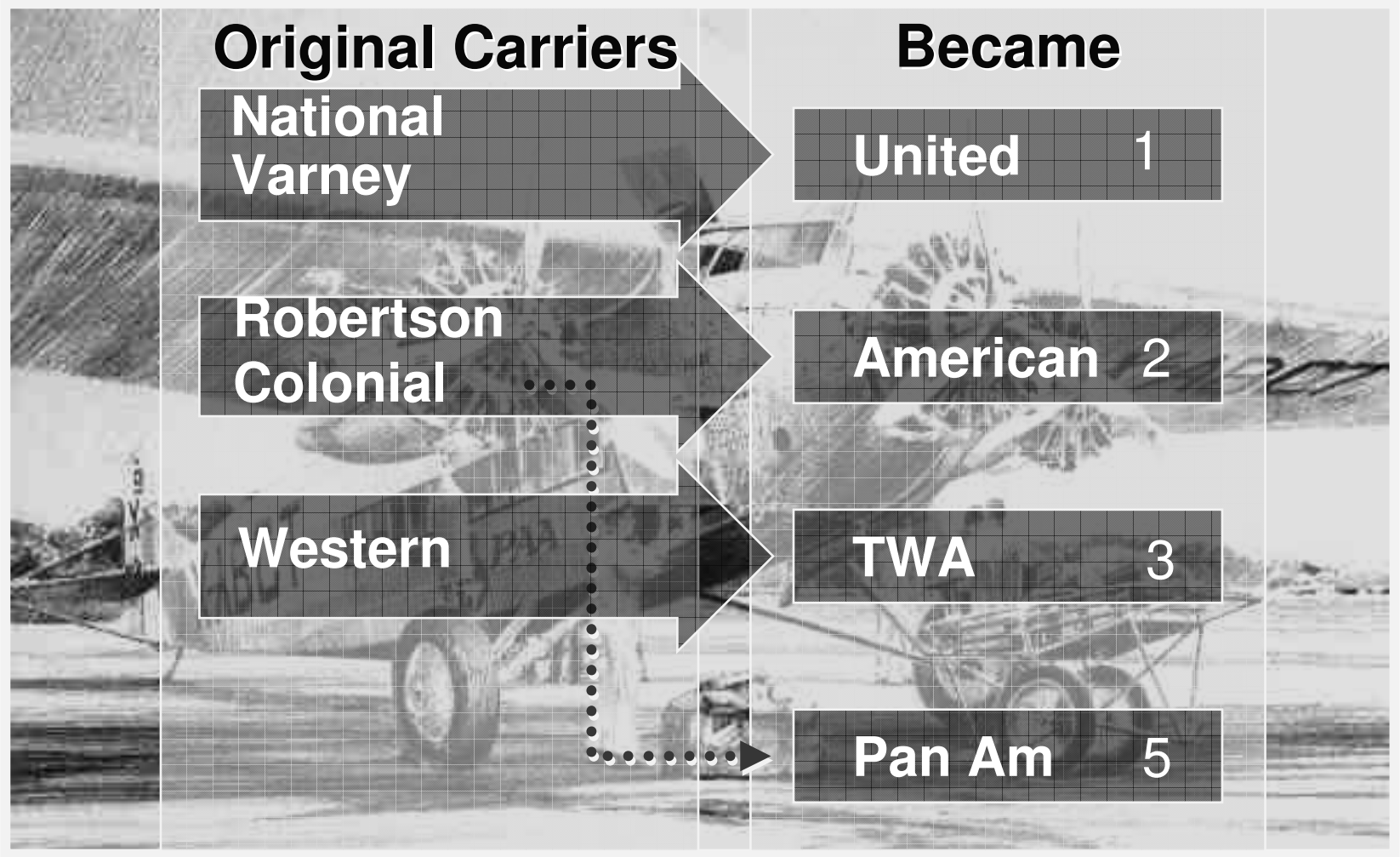
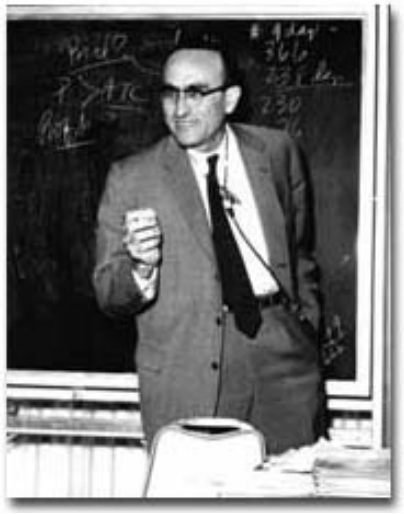
A Little US Airline History

The Contract Air Mail Act of 1925



The 1978 US Domestic Airline Deregulation Act



- **The 1978 US Domestic Airline Deregulation Act mandated:**
  - End of route restrictions 12/31/81
  - End of rate regulation 1/1/83
- **The CAB actually moved faster ending route regulation in 1979 and rate regulation in 1980**
- **CAB was sunset 1/1/85**

Canadian Deregulation was More Deliberate*

- **Air Canada Act of 1977 mandated that AC should operate with "due regard to sound business principles and in particular the contemplation of profit"**
- **On 10 May 1984, the Minister of Transport liberalized air transport by allowing carriers to compete on routes anywhere in Canada**
- **"Freedom to Move" (Jan 1 1988) Greater reliance on competition and market forces; and an accessible and not excessively costly or time-consuming regulatory process**
- **In February 1995, Canada and the United States signed the "Open Skies" treaty, allowing Canadian carriers unlimited route rights from any point in Canada to any point in the United States**
- ***Copied shamelessly from:**

  THE CANADIAN AIRLINE INDUSTRY
  John Christopher, Joseph P. Dion
  Science and Technology Division
  Revised 14 November 2002

Quiz: In 1978, Who was the Biggest Texas-Based Airline?

American Airlines	$2.7 bn	NYC
Braniff International	$1.0 bn	DFW
Continental Airlines	$0.8 bn	LAX
	$0.2 bn	HOU
Southwest Airlines — Just Plane Smart	<$0.1 bn	DAL

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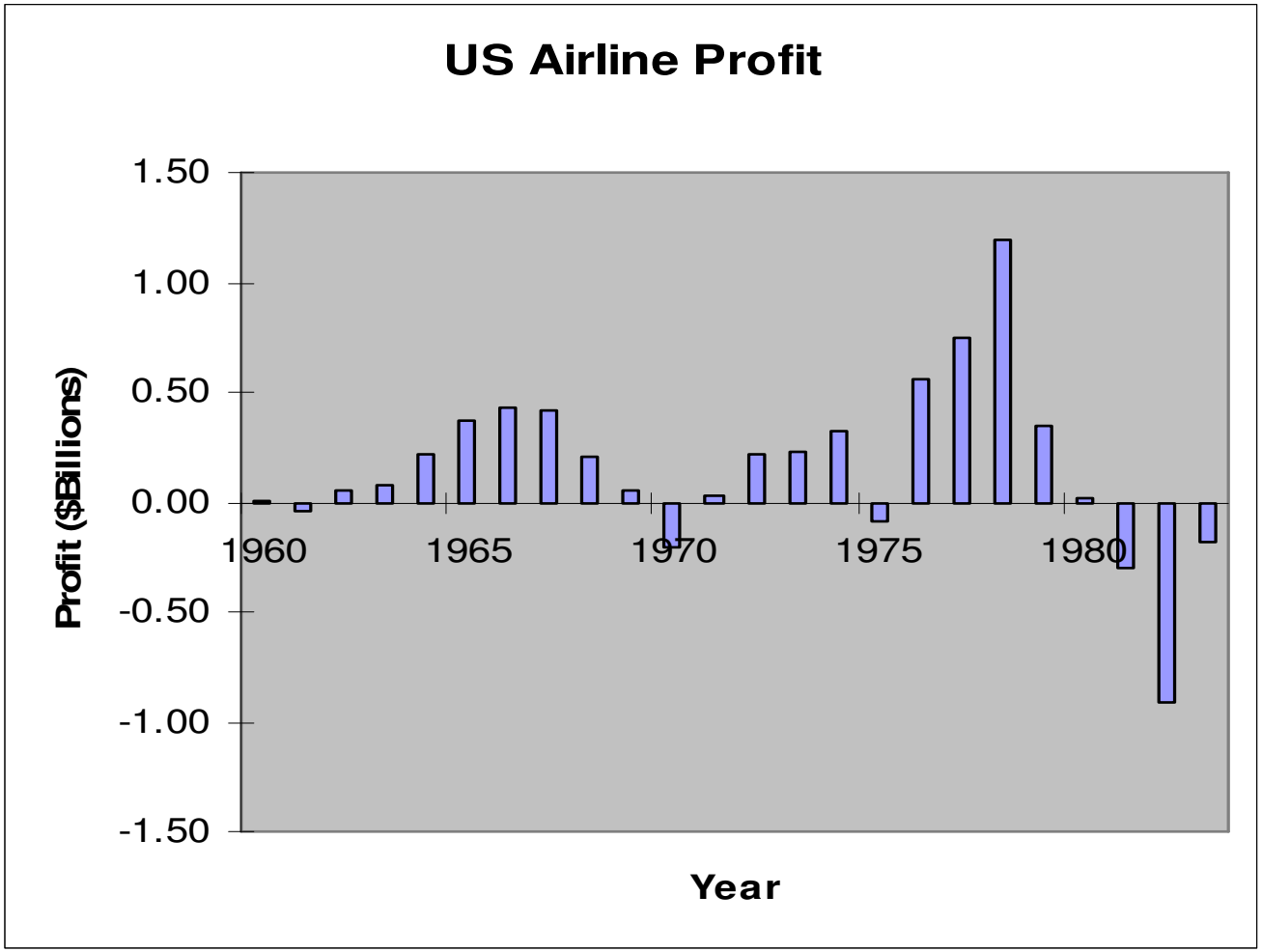
BI was the Rock-star of the US Airline Industry

BI was the First Major Casualty of Deregulation

Deregulation Tanked the US Industry



Deregulation also Killed Many Systems

RIPACS

Reservation Inventory Planning and Control System

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US Airlines Evolved Following Deregulation

- Pricing – Large variety of fares and restrictions
- Scheduling – Hub and spoke network design
- Sales – Loyalty programs
- Distribution – Many selling channels
- Simplicity -- Networks, Fleets, Fares

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Revenue Management Development

The Most Important Aspects of RM Developed in the Post-Deregulation Environment

- 1960s – Overbooking
- 1980s – Discount Allocation
- 1990s – O&D Control
- 2000s – Channel Control, Customer-based RM

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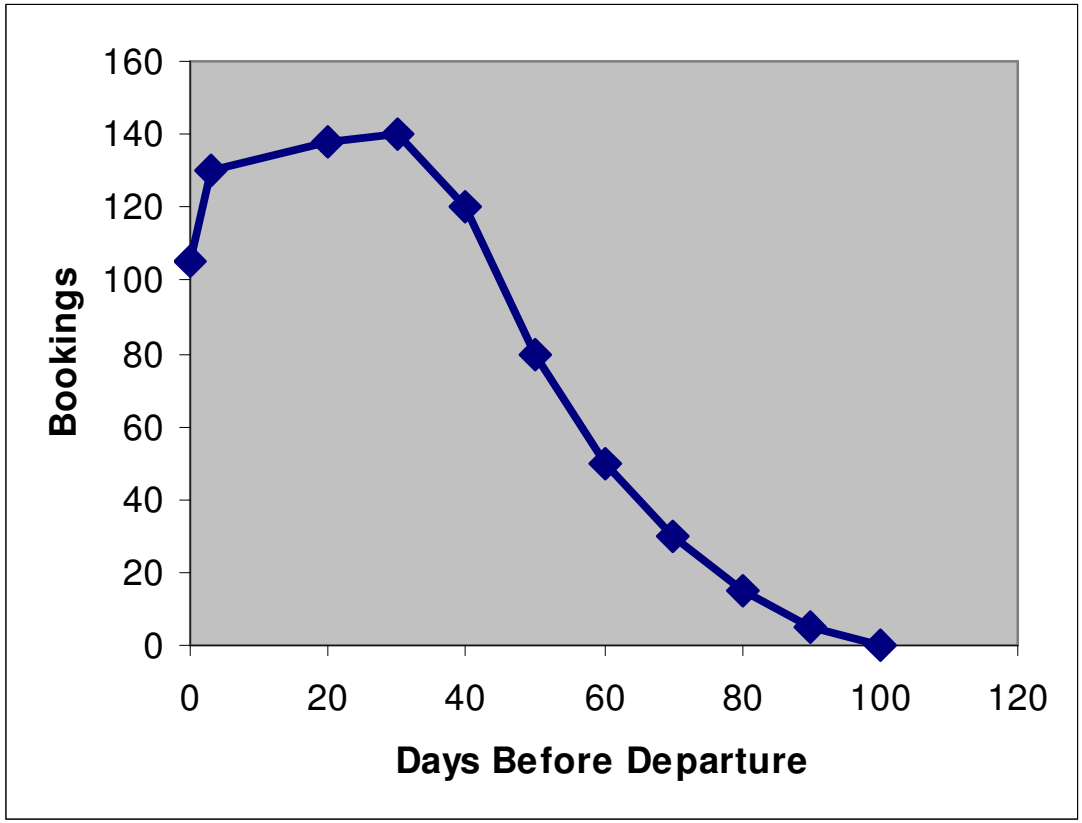
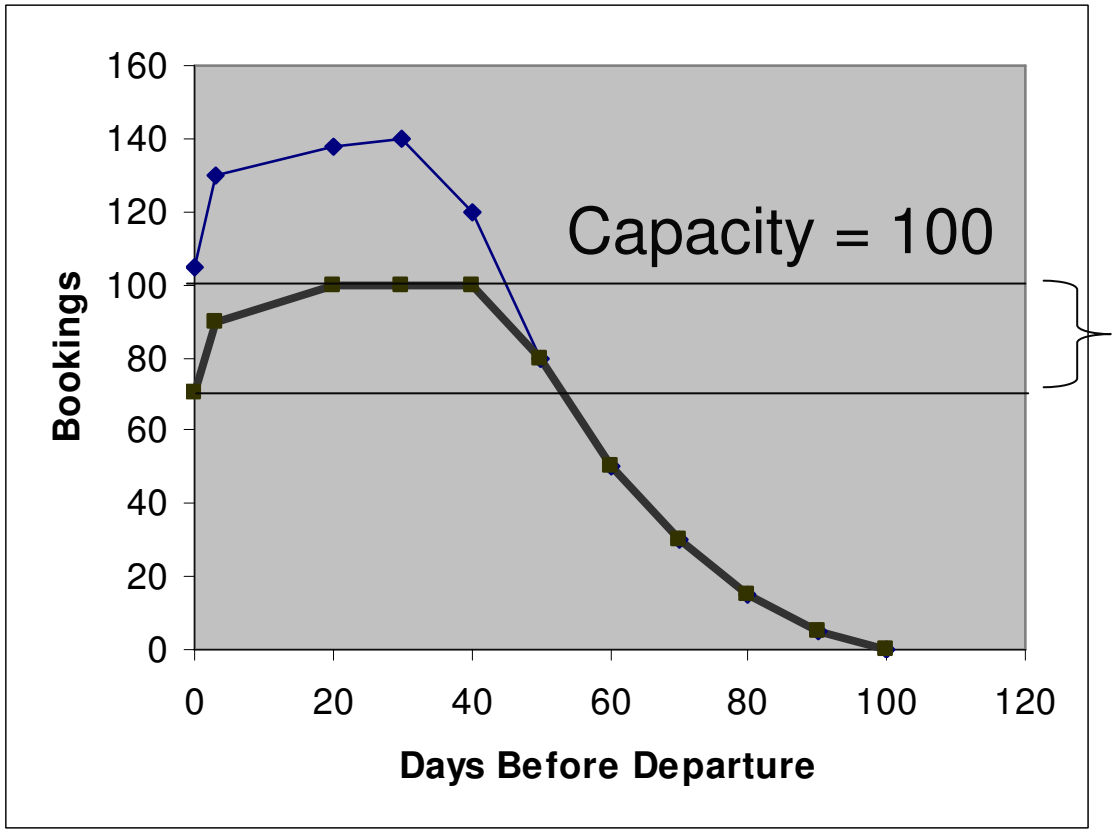
Overbooking

Overbooking – Sell Beyond Physical Capacity

Typical booking, cancellation, no-show profile

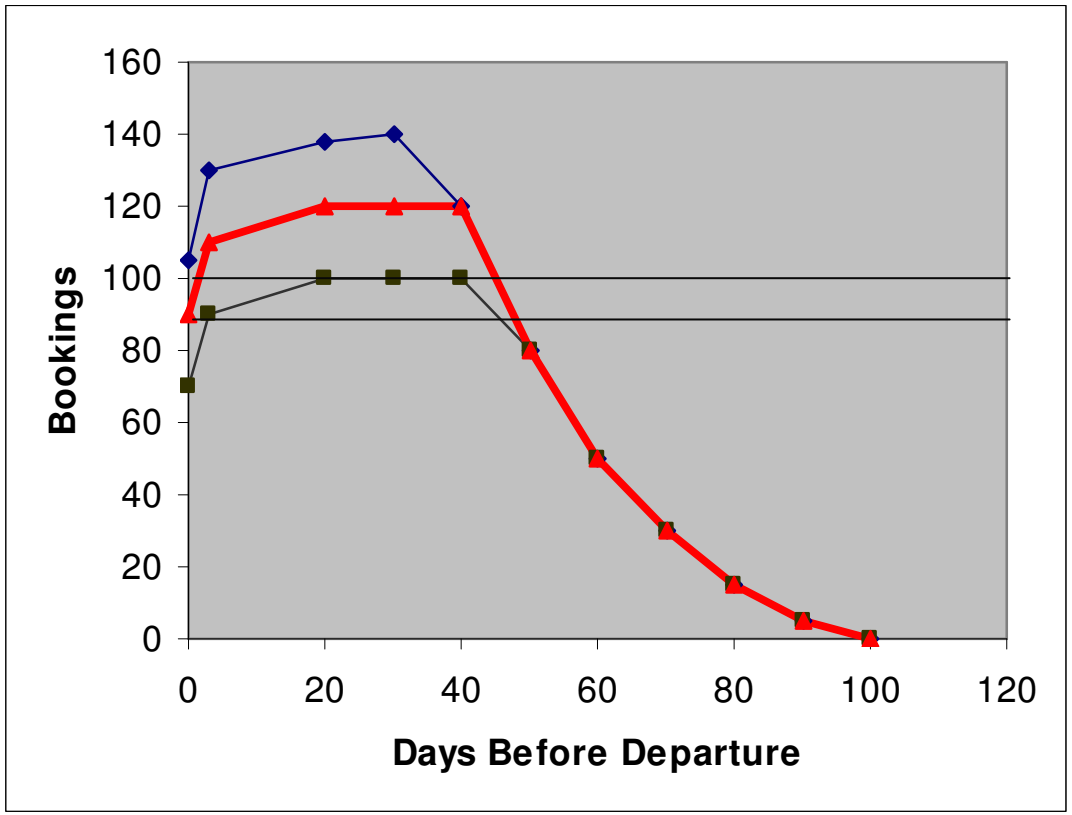


Capping Reservations at Capacity Results in Spoilage



Overbooking Reduces Spoilage

- **Uncertainty in the distribution of show-ups leads to probabilities of both spoilage and oversales**
- **Overbooking models maximize expected profit**



Annual Benefit: $200mm

Controls Required: 1mm

In 1982 Overbooking Models Went Nuts

- Prior to De-regulation, oversale rates were limited due to costs. “Mad Money” was estimated at $3000 per passenger
- In 1982, the introduction of Volunteer Programs and Travel Vouchers cut the cost per oversale by 95%
- The models were very happy, they drove overbooking and oversale rates to record levels
- Maintaining reasonable service at airports required tightening of constraints on oversale risk
- We dualized the service constraint and reintroduced additional oversale costs

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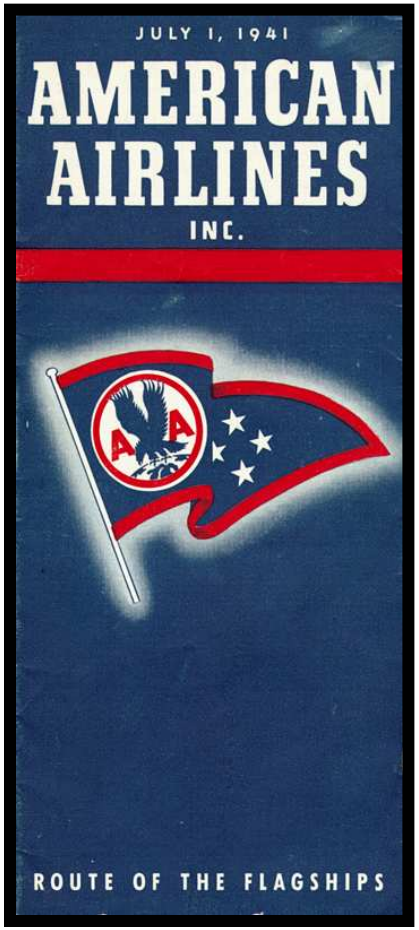
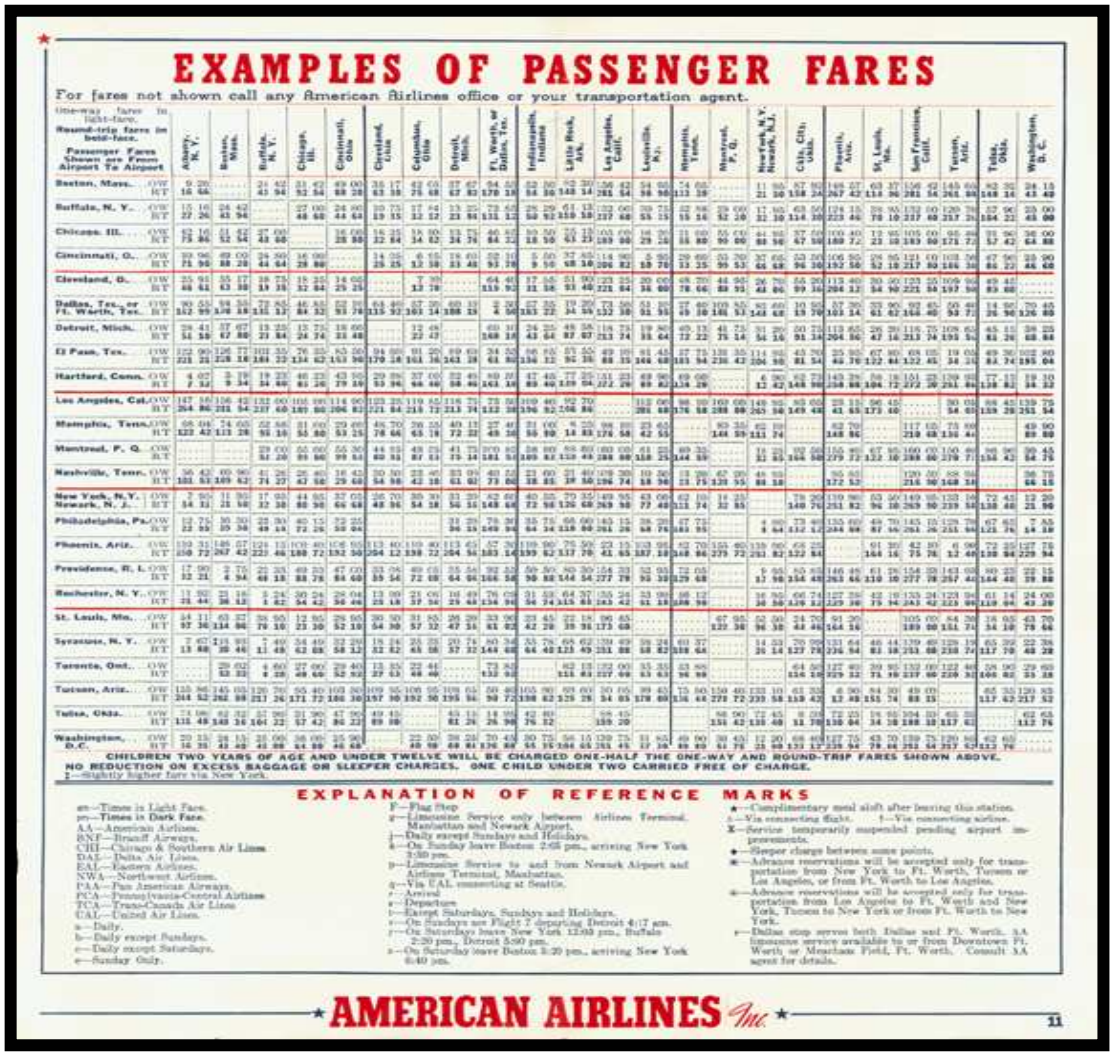
Discount Allocation

In the 1940s American Airlines Published Fares on the Back of Their Timetable





EXAMPLES OF PASSENGER FARES

For fares not shown call any American Airlines office or your transportation agent.

CHILDREN TWO YEARS OF AGE AND UNDER TWELVE WILL BE CHARGED ONE-HALF THE ONE-WAY AND ROUND-TRIP FARES SHOWN ABOVE. NO REDUCTION ON EXCESS BAGGAGE OR SLEEPER CHARGES. ONE CHILD UNDER TWO CARRIED FREE OF CHARGE.

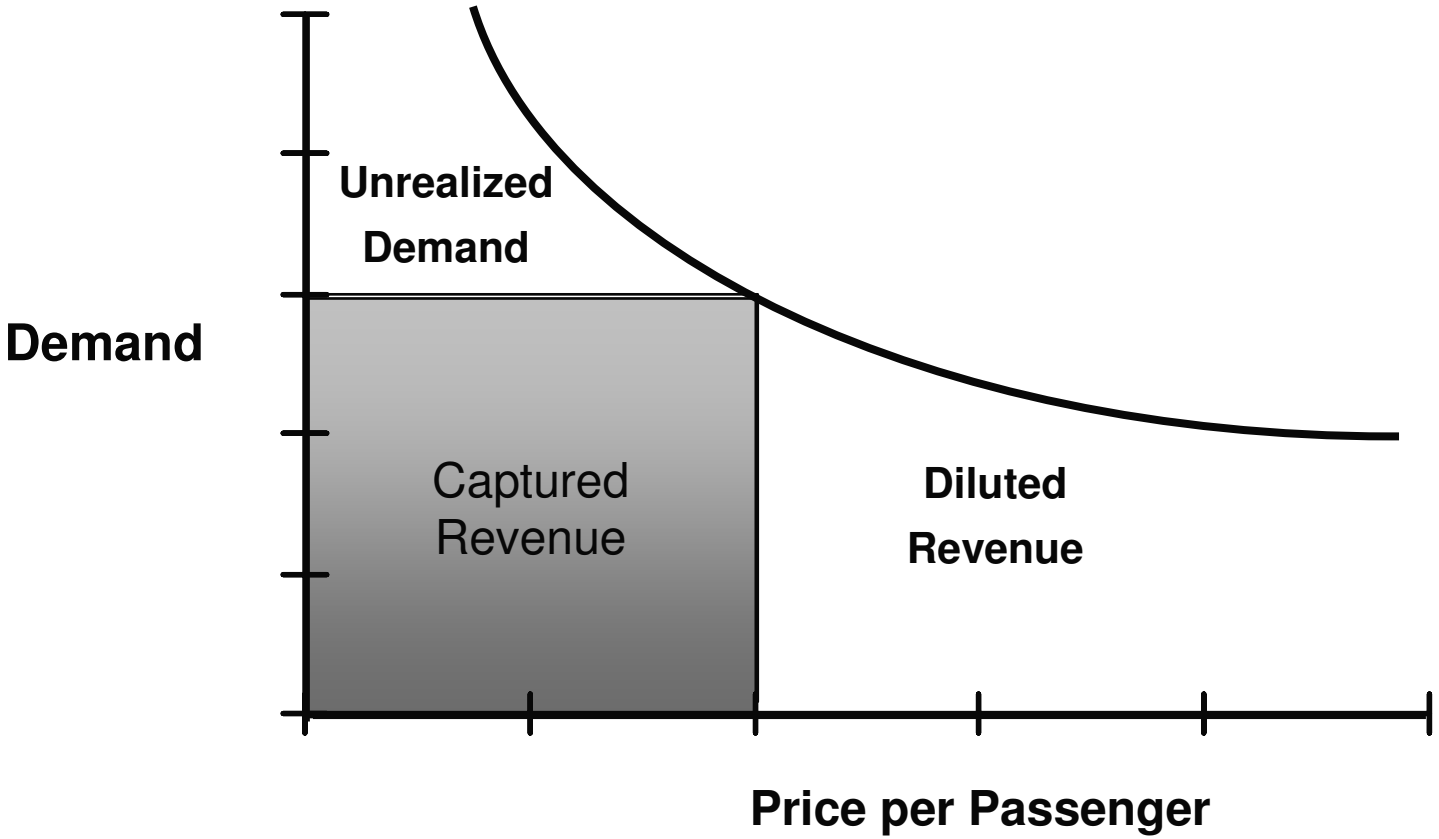
‡—Slightly higher fare via New York.

EXPLANATION OF REFERENCE MARKS

am—Times in Light Face.
pm—Times in Dark Face.
AA—American Airlines.
BNF—Braniff Airways.
CBI—Chicago & Southern Air Lines.
DAL—Delta Air Lines.
EAL—Eastern Airlines.
NWA—Northwest Airlines.
PAA—Pan American Airways.
PCA—Pennsylvania-Central Airlines.
TCA—Trans-Canada Air Lines.
UAL—United Air Lines.
a—Daily.
b—Daily except Sundays.
c—Daily except Saturdays.
e—Sunday Only.
F—Flag Stop
g—Limousine Service only between Airlines Terminal, Manhattan and Newark Airport.
j—Daily except Sundays and Holidays.
k—On Sunday leave Boston 2:05 pm., arriving New York 3:30 pm.
p—Limousine Service to and from Newark Airport and Airlines Terminal, Manhattan.
q—Via UAL connecting at Seattle.
r—Arrival
s—Departure
t—Except Saturdays, Sundays and Holidays.
v—On Sundays see Flight 7 departing Detroit 4:17 pm.
x—On Saturdays leave New York 12:00 pm., Buffalo 2:20 pm., Detroit 5:00 pm.
z—On Saturday leave Boston 3:20 pm., arriving New York 6:40 pm.
★—Complimentary meal aloft after leaving this station.
△—Via connecting flight. †—Via connecting airline.
X—Service temporarily suspended pending airport improvements.
✦—Sleeper charge between some points.
✱—Advance reservations will be accepted only for transportation from New York to Ft. Worth, Tucson or Los Angeles, or from Ft. Worth to Los Angeles.
✧—Advance reservations will be accepted only for transportation from Los Angeles to Ft. Worth and New York, Tucson to New York or from Ft. Worth to New York.
⌐—Dallas stop serves both Dallas and Ft. Worth. AA limousine service available to or from Downtown Ft. Worth or Meacham Field, Ft. Worth. Consult AA agent for details.

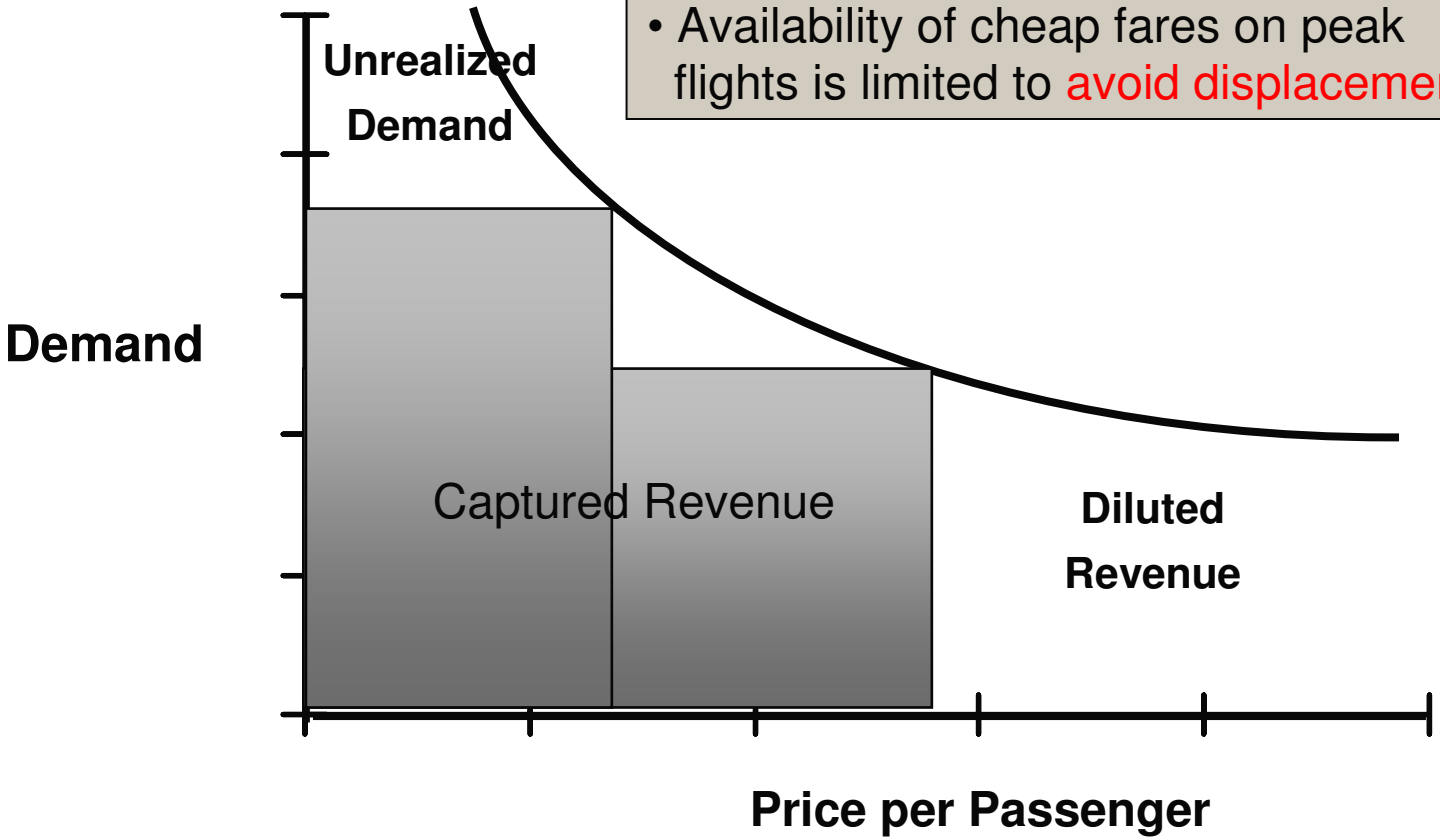
★AMERICAN AIRLINES Inc.★ 11

Simple Pricing Leaves Money on the Table



Multiple Price-points Achieve More Revenue

Capture more revenue with more fares if:
- Demand is segmented to avoid dilution
- Availability of cheap fares on peak flights is limited to avoid displacement



Class Code Allocations

Booking Request

Stop Selling Discounts When

$$175 * P(DemandToCome \geq SeatsAvail) \geq 100$$

$$p(Dmd_1 > alloc_1) \leq \frac{rev_2}{rev_1}$$

OR

Hold for Future Request

Sell out

Future Fare = $175

OR

Seats remaining

Empty Seat

$0

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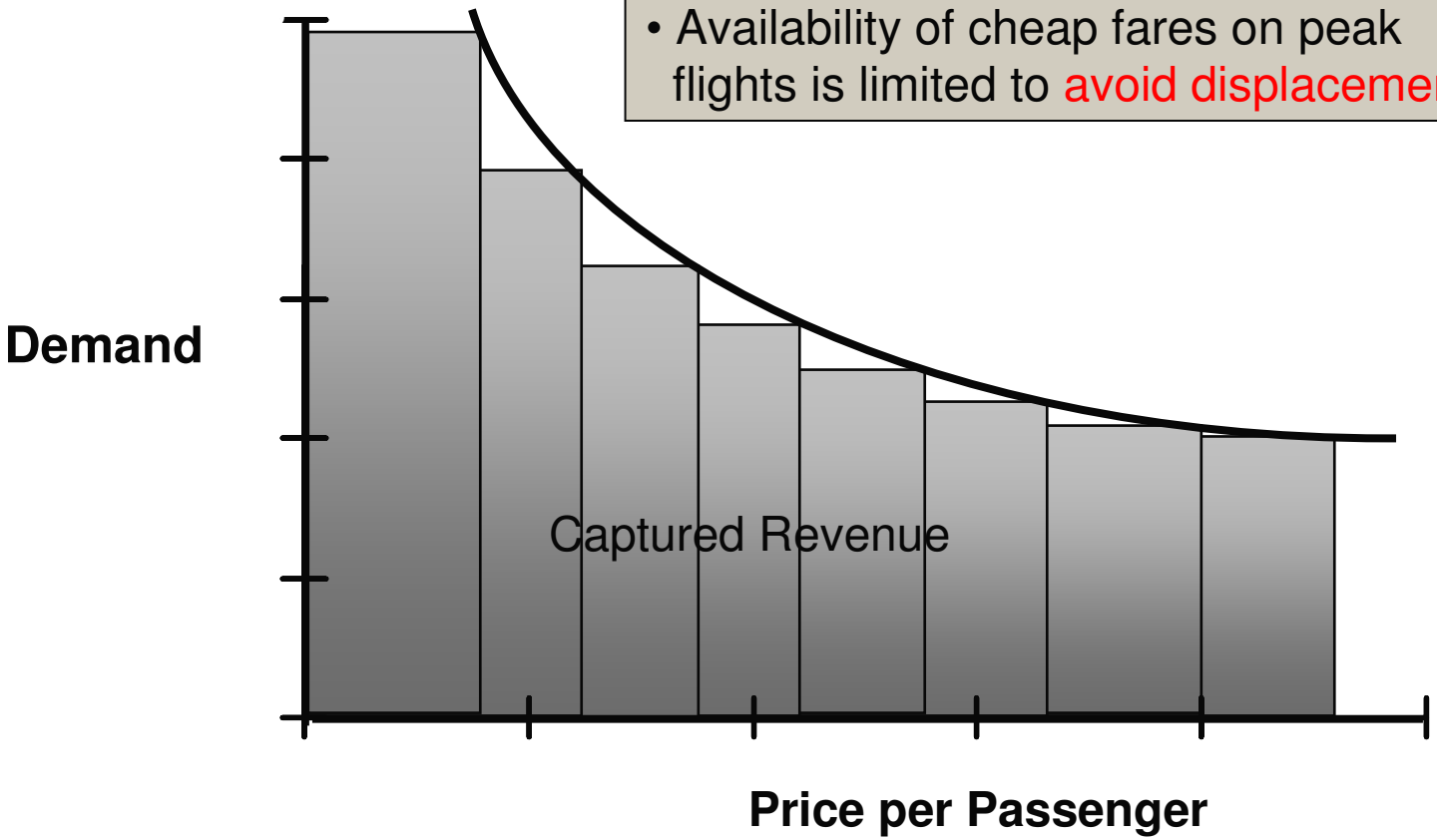
If Having 2 Fares is Good then 40 is Better

Capture more revenue with more fares if:
- Demand is segmented to avoid dilution
- Availability of cheap fares on peak flights is limited to avoid displacement



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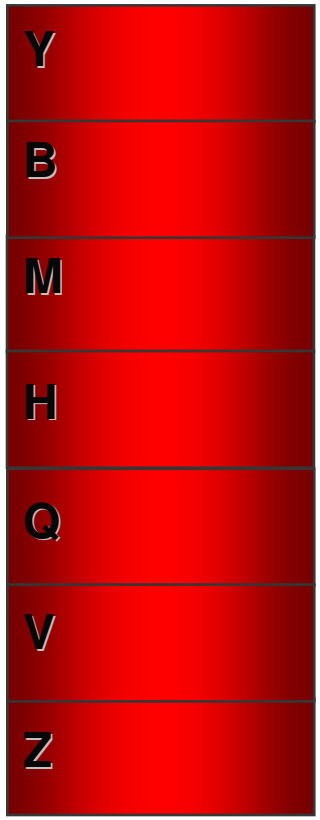
Controlling Multiple Fares: EMSR



Expected Marginal Seat Revenue

Ry≥Rb≥….≥Rz

Set $alloc_n$ such that:

$$p(\sum_{p\in 1\ldots n} Dmd_p > alloc_n) \leq \frac{rev_{n+1}}{rev_{1\ldots n}}$$

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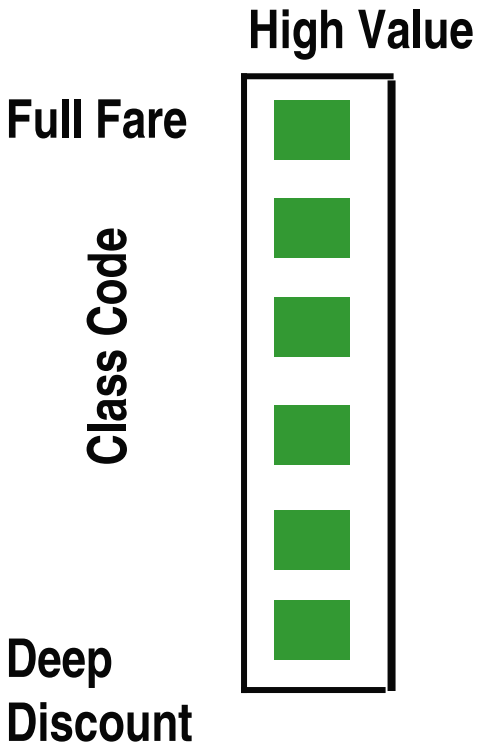
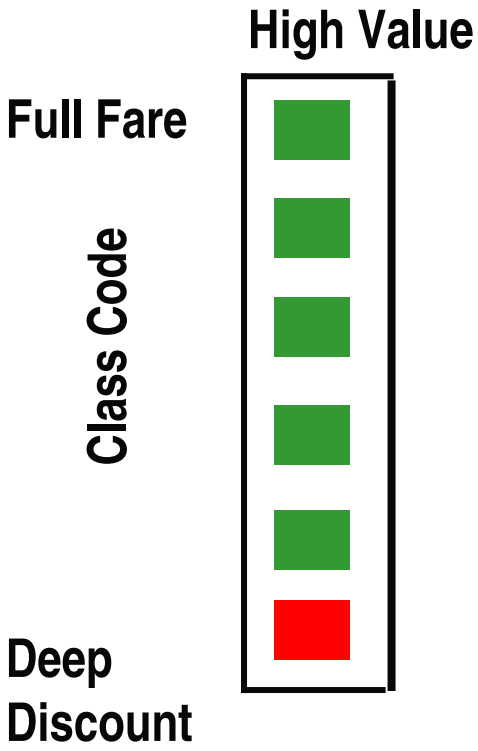
Class Code Allocations

Last Seat Availability



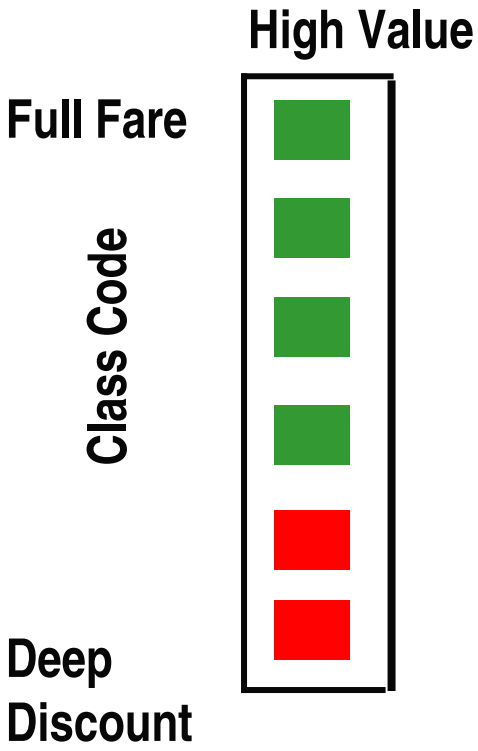
Class Code Allocations

Last Seat Availability



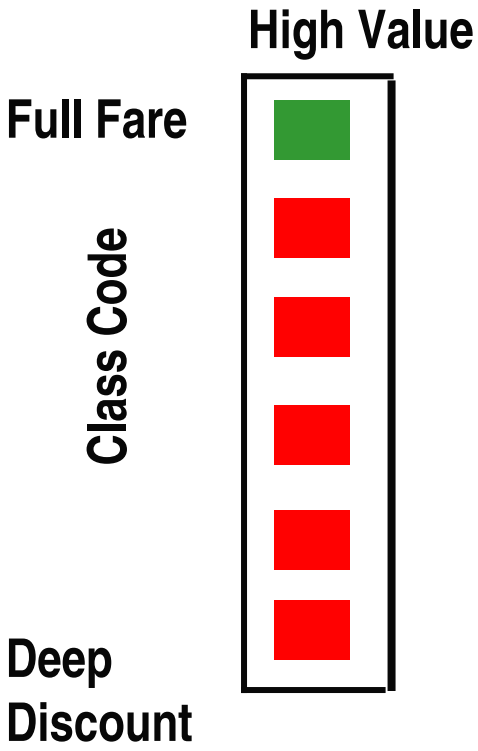
Class Code Allocations

Last Seat Availability



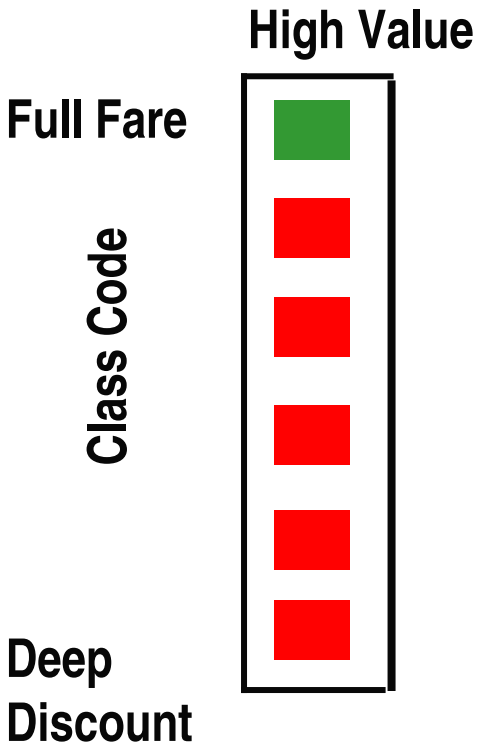
Class Code Allocations

Last Seat Availability



Class Code Allocations

Last Seat Availability



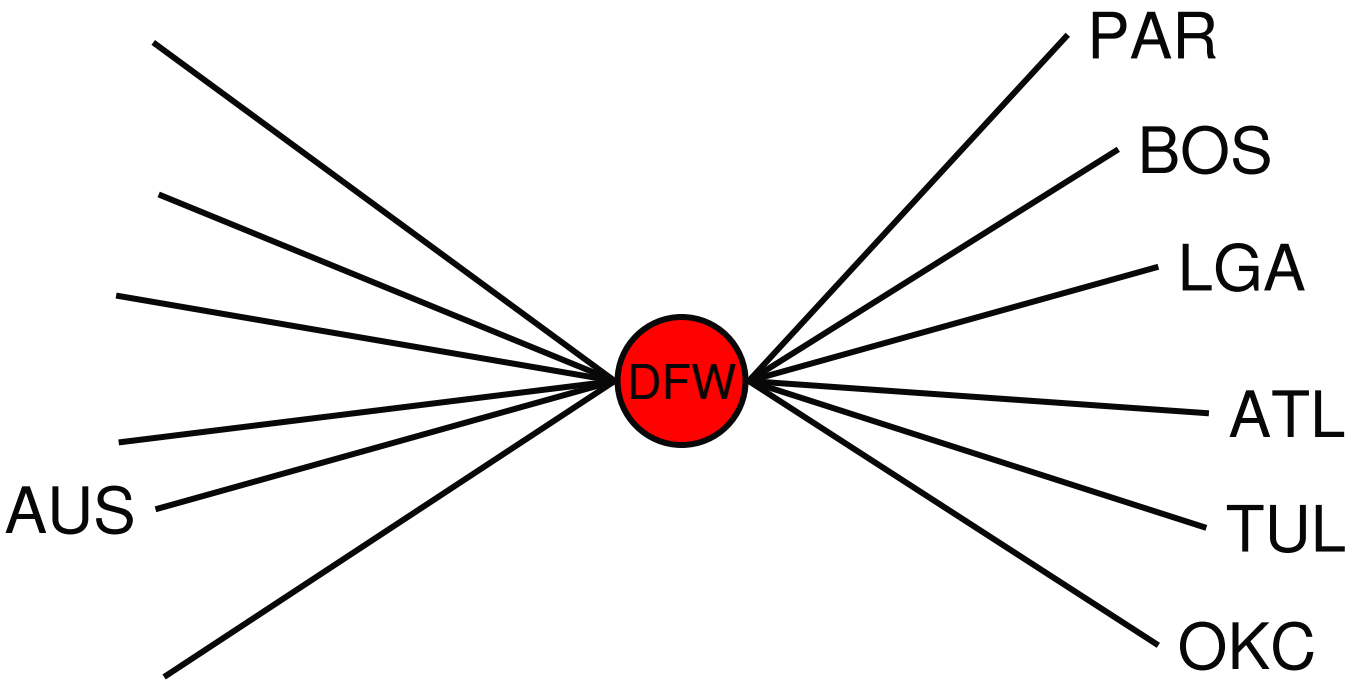
Annual Benefit: $400mm

Controls Required: 10mm

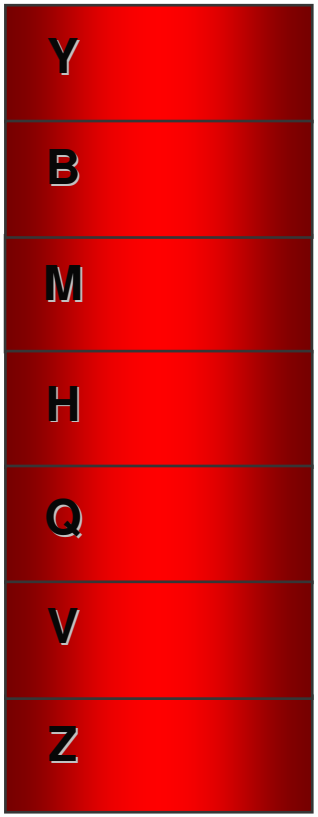
In the 1980s US Domestic Carriers Developed Concentrated Hub and Spoke Networks

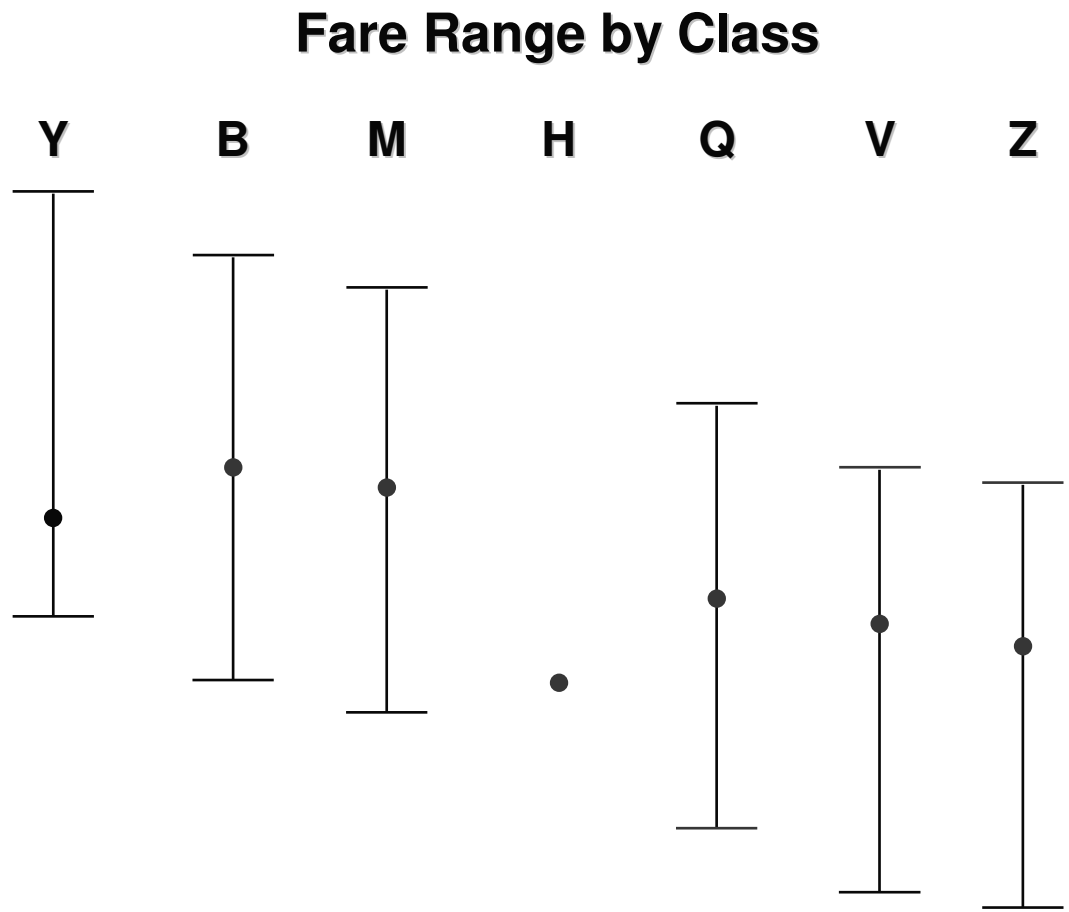
Each flight can carry passengers in many markets

By Serving Many O&Ds, the Range of Revenue by Class Code Expanded

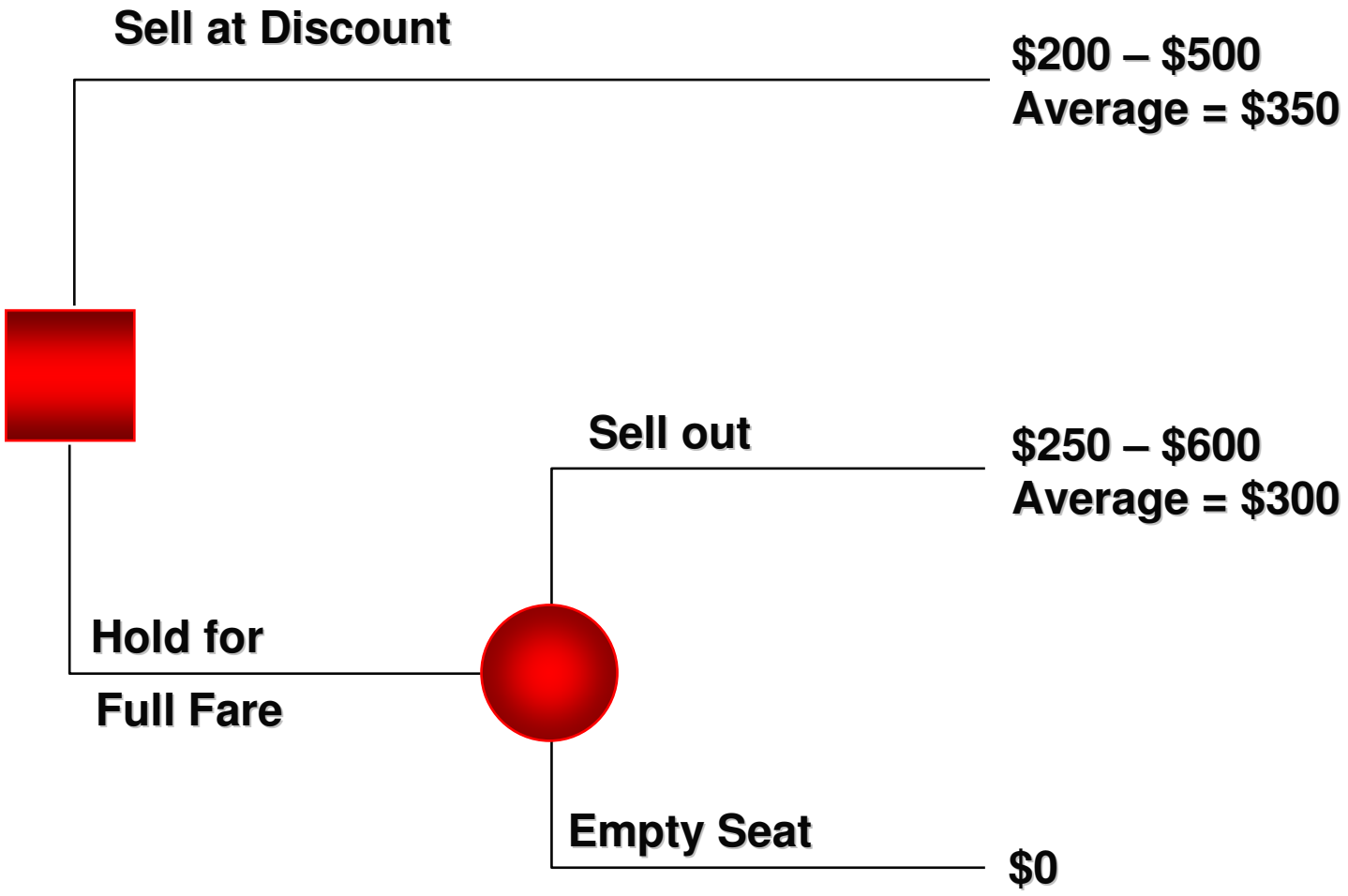


Due to the Variety of O&Ds in each Class, Revenues Became Inconsistent





Fare Overlap Invalidated the EMSR Approach to Discount Controls



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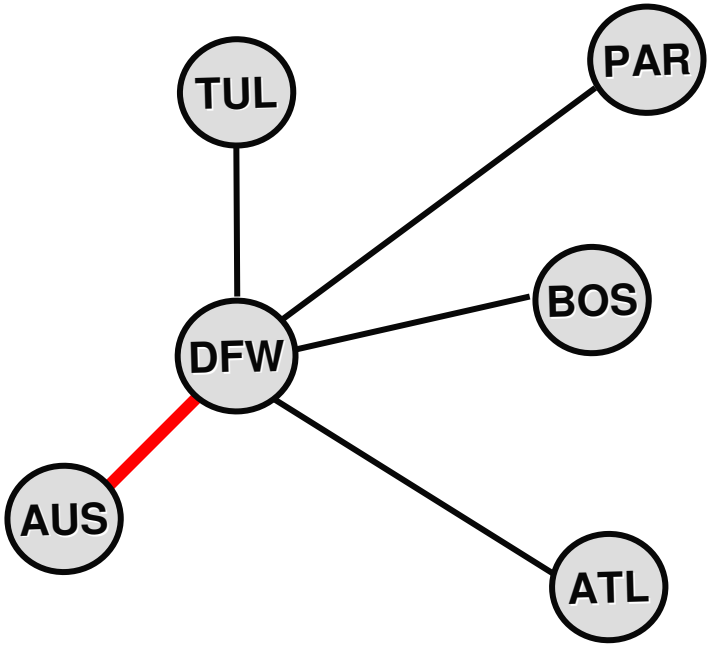
Origin-Destination RM

Virtual Nesting Restored Order to Revenues



Org	Dst	Class	Fare	Bucket
AUS	PAR	Y	$2,000	Y0
AUS	BOS	Y	$1,500	
AUS	PAR	B	$1,000	Y1
AUS	ATL	Y	$800	Y2
AUS	BOS	B	$750	
AUS	ATL	B	$400	Y3
AUS	TUL	Y	$300	Y4

Origin & Destination (O&D) Control

Annual Benefit: $500mm

Controls Required: 100mm

Origin & Destination (O&D) Control

Annual Benefit: $500mm

Controls Required: 100mm

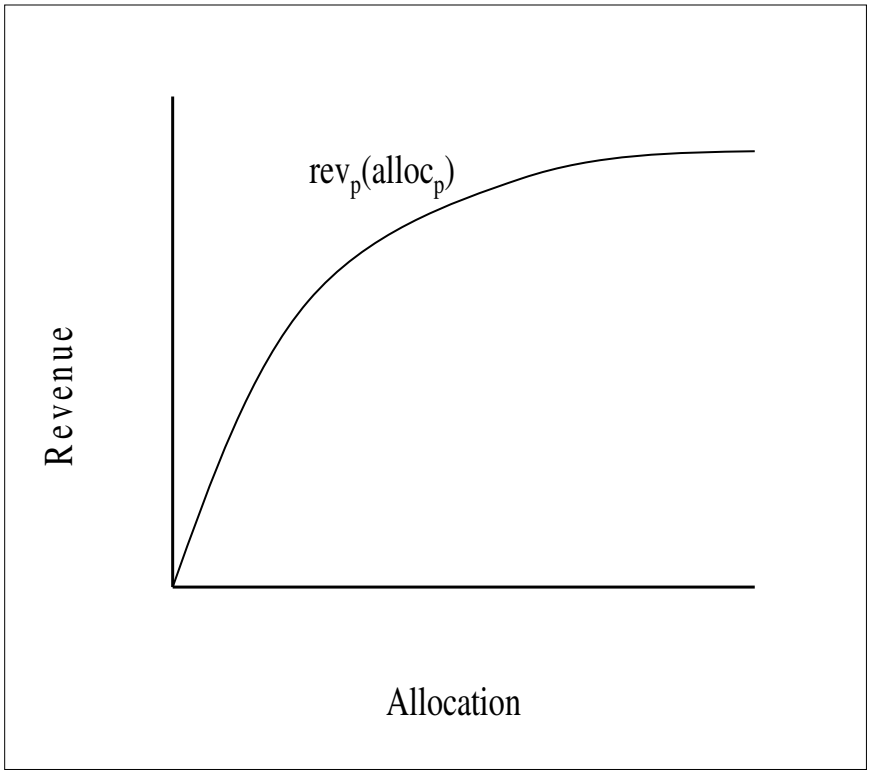
Origin & Destination (O&D) Control

Annual Benefit: $500mm

Controls Required: 100mm

A Network RM Optimization Model

- Maximize revenue by allocating space to each O&D fare class, passenger type (p)
- Subject to total allocation on each flight leg LE capacity
- Due to uncertainty in future demand, bookings and revenue are non-linear functions of the allocation



ODRM Formulation

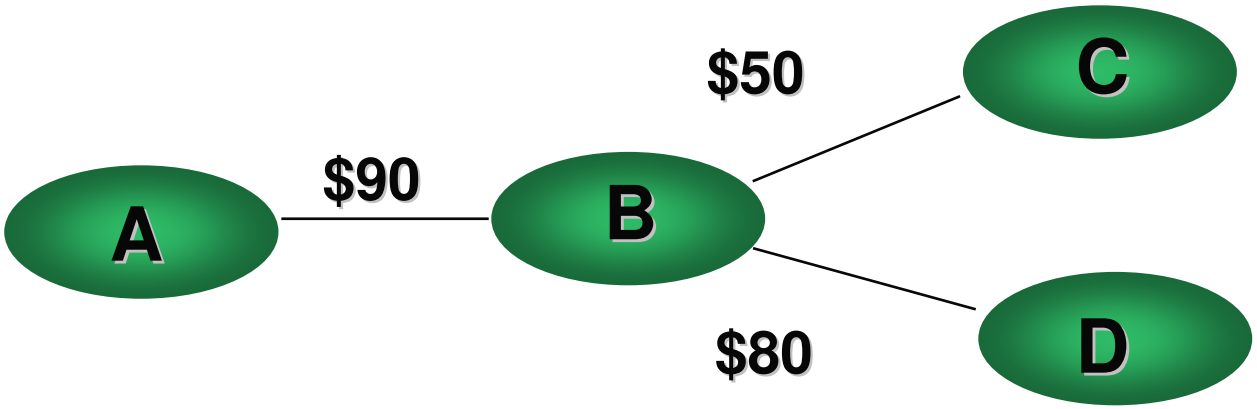
$$\text{Maximize:} \quad \sum_{p \in P} rev_p E(traf_p \mid Dmd_p, alloc_p)$$

$$\text{Subject to:} \quad \sum_{p \in f} alloc_p \leq cap_f \, \forall f \in F$$

$$alloc_p \geq 0, \forall p \in P$$

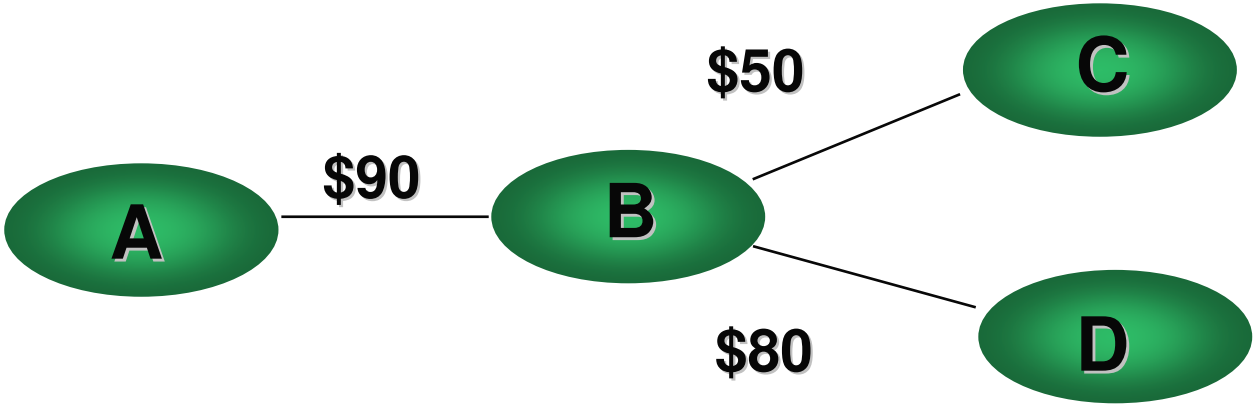
- The optimal values of dual variables on the capacity constraints represent the opportunity cost of selling a seat on this flight
- These values, referred to as Bid Prices, are used by most advanced airlines to control availability

Bid Price Inventory Control – Locals



OD	Class	Fare	Bid Price	Net Revenue	Availability
AB	Y	$79	$90	-$11	Closed
AB	B	$49	$90	-$41	Closed
BC	Y	$69	$50	$19	Open
BC	B	$45	$50	-$5	Closed
BD	Y	$89	$80	$9	Open
BD	B	$69	$80	-$11	Closed

Bid Price Inventory Controls – Connections



OD	Class	Fare	Bid Price	Net Revenue	Availability
AC	Y	$189	$140	$49	Open
AC	B	$129	$140	-$11	Closed
AD	Y	$249	$170	$79	Open
AD	B	$199	$170	$29	Open

O&D Control using Bid Prices

Annual Benefit: $600mm

Controls Required: **10mm**

O&D Control using Bid Prices

Annual Benefit: $600mm

Controls Required: **10mm**

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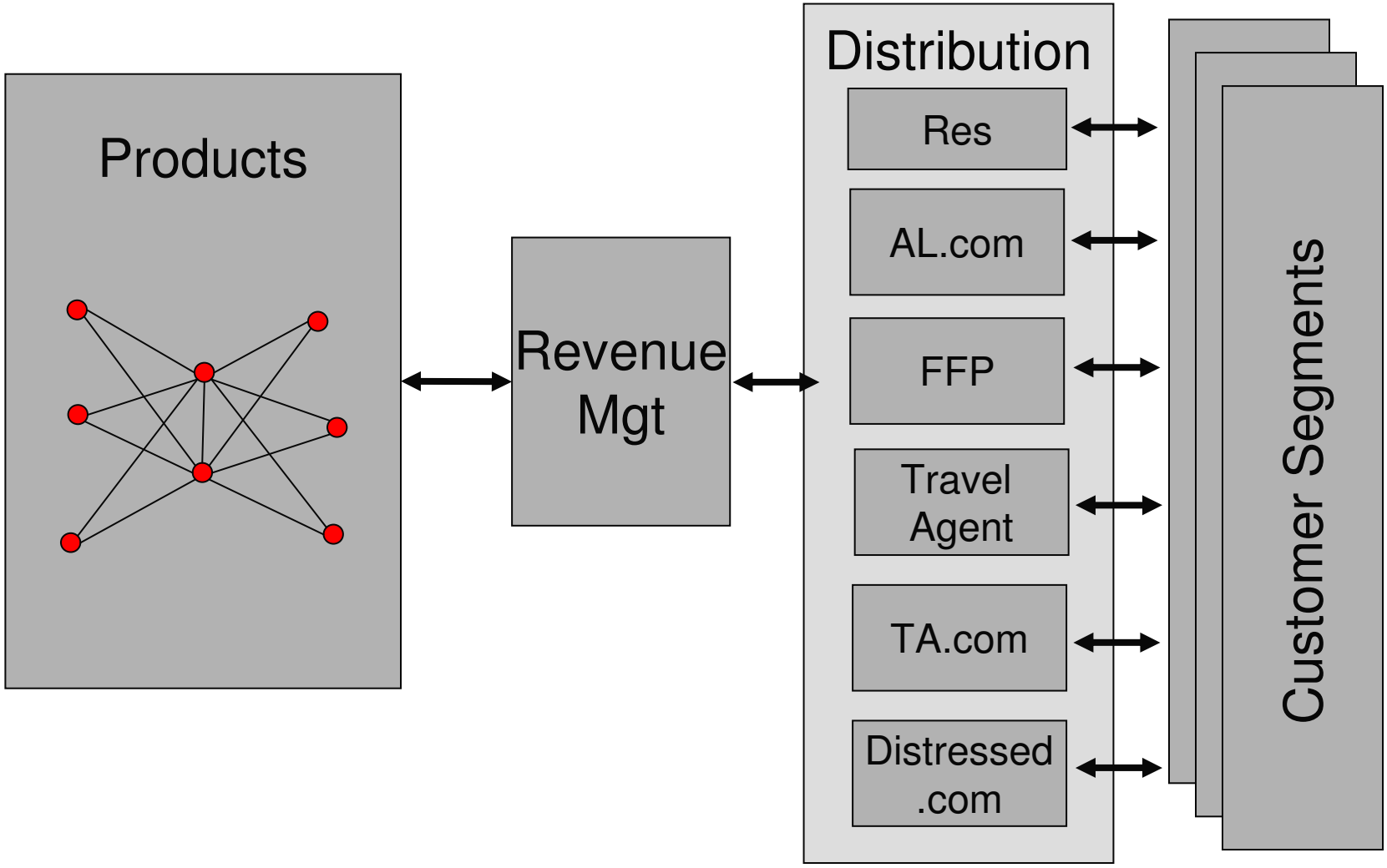
Channel RM

Distribution Channel Segmentation



2000s Distribution Channel Segmentation

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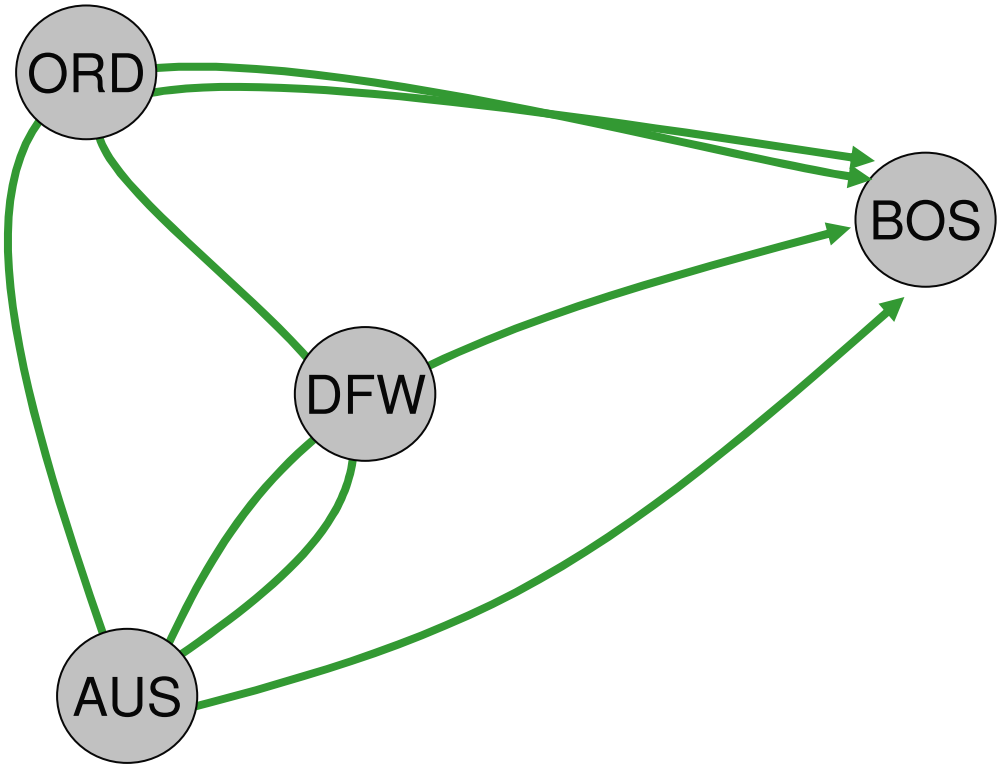
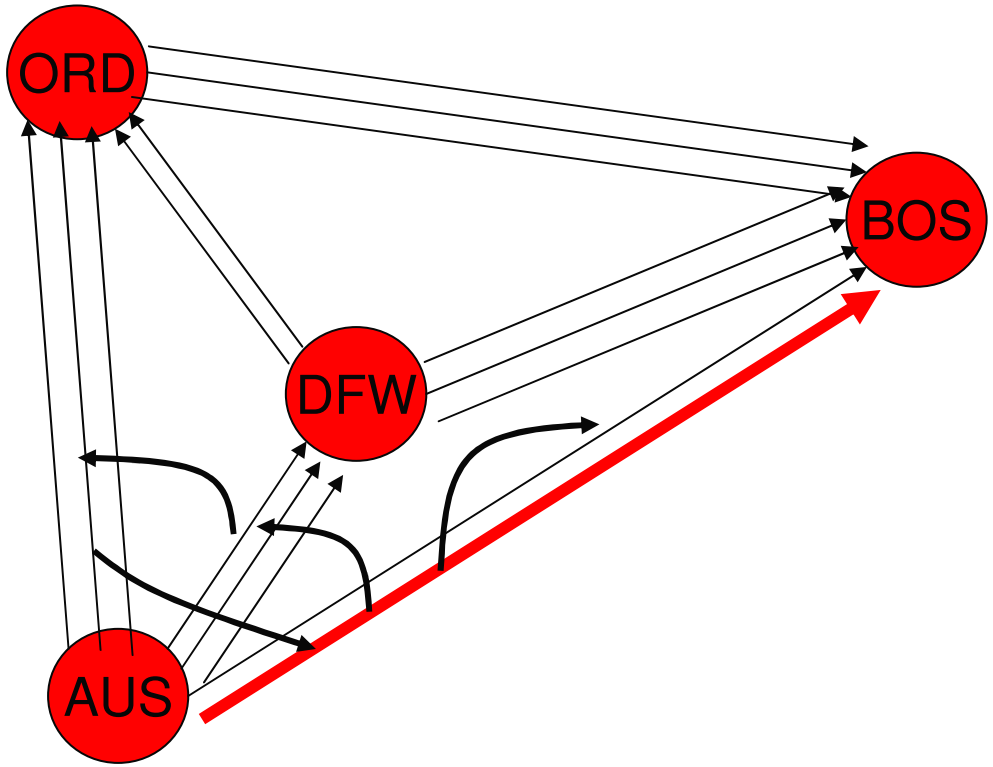
Customer-based RM

With Restriction-free Pricing and Transparent Shopping, What is Demand?



Forecasting Demand for a Flight Class, or a Path Class is a Difficult Proposition



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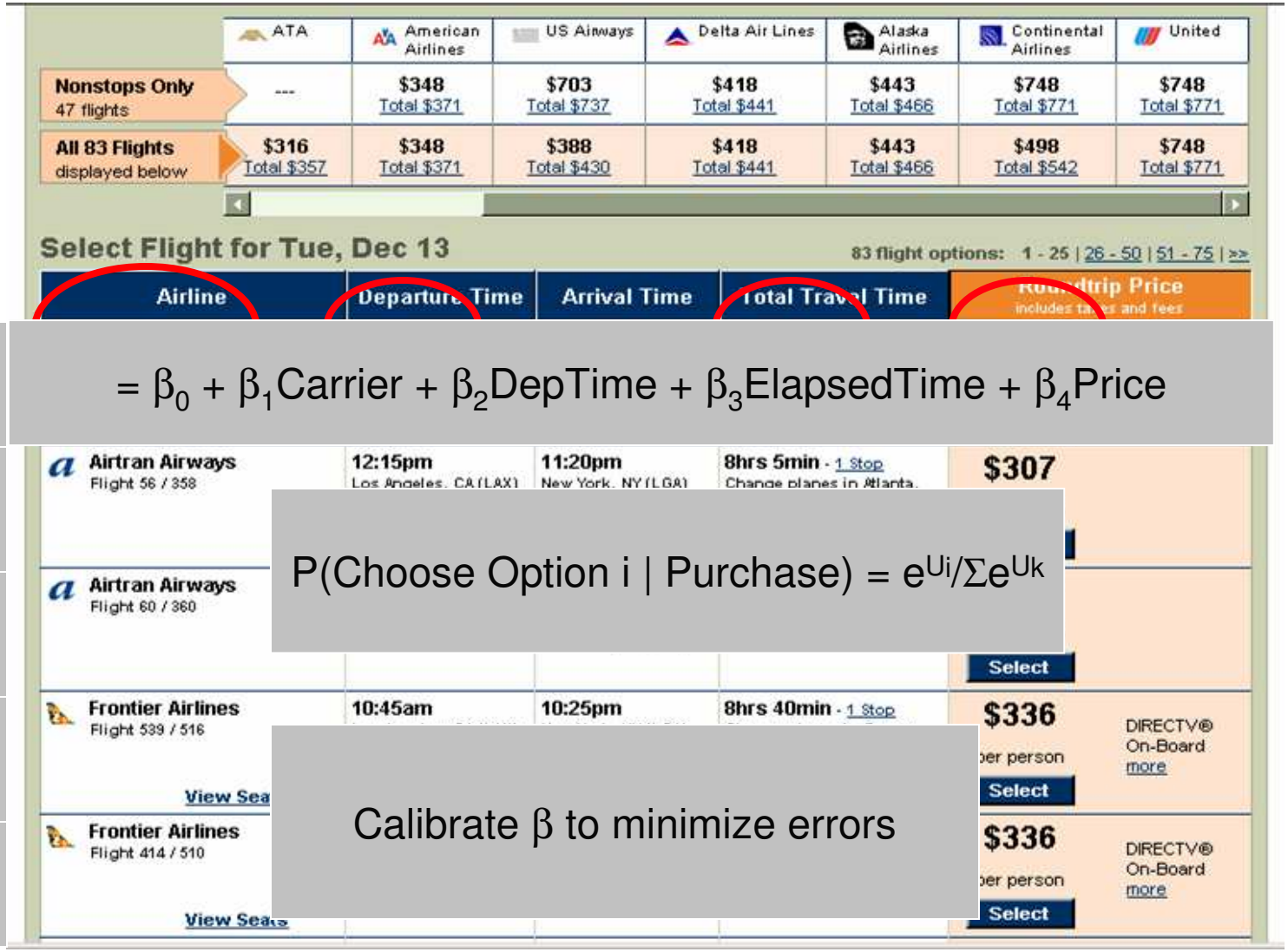
Customer Choice Modeling Provides Situational Awareness of Demand



U_1	$= \beta_0 + \beta_1 Carrier + \beta_2 DepTime + \beta_3 ElapsedTime + \beta_4 Price$
U_2	
U_3	
U_4	
U_5	

$$P(\text{Choose Option i} \mid \text{Purchase}) = e^{Ui}/\Sigma e^{Uk}$$

Calibrate β to minimize errors

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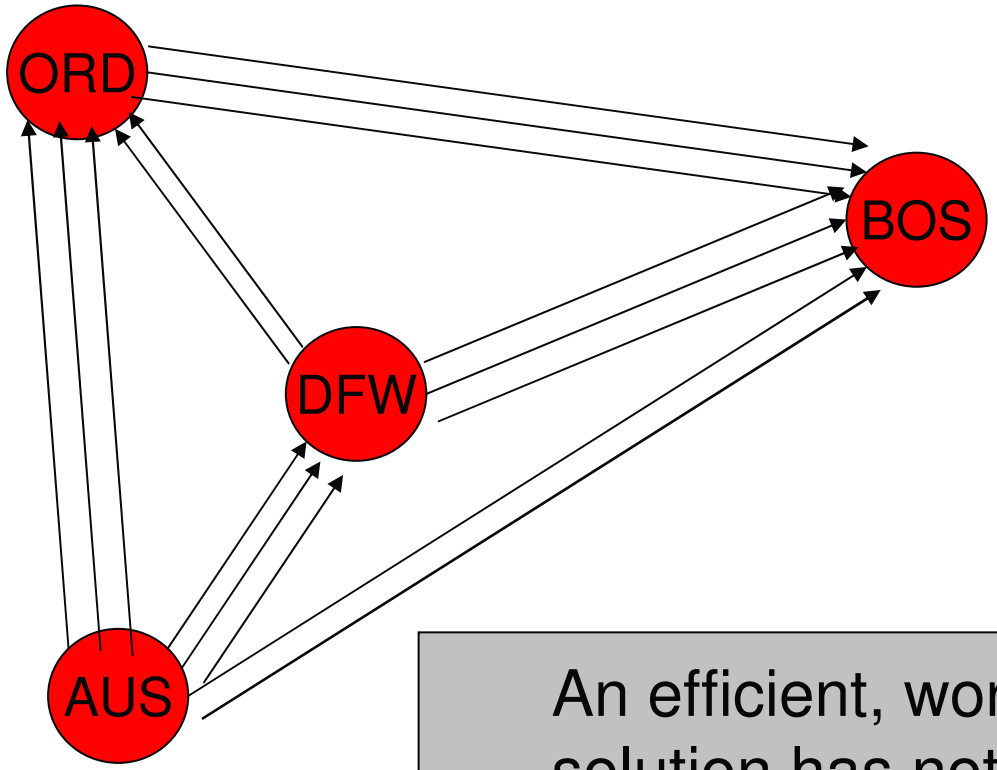
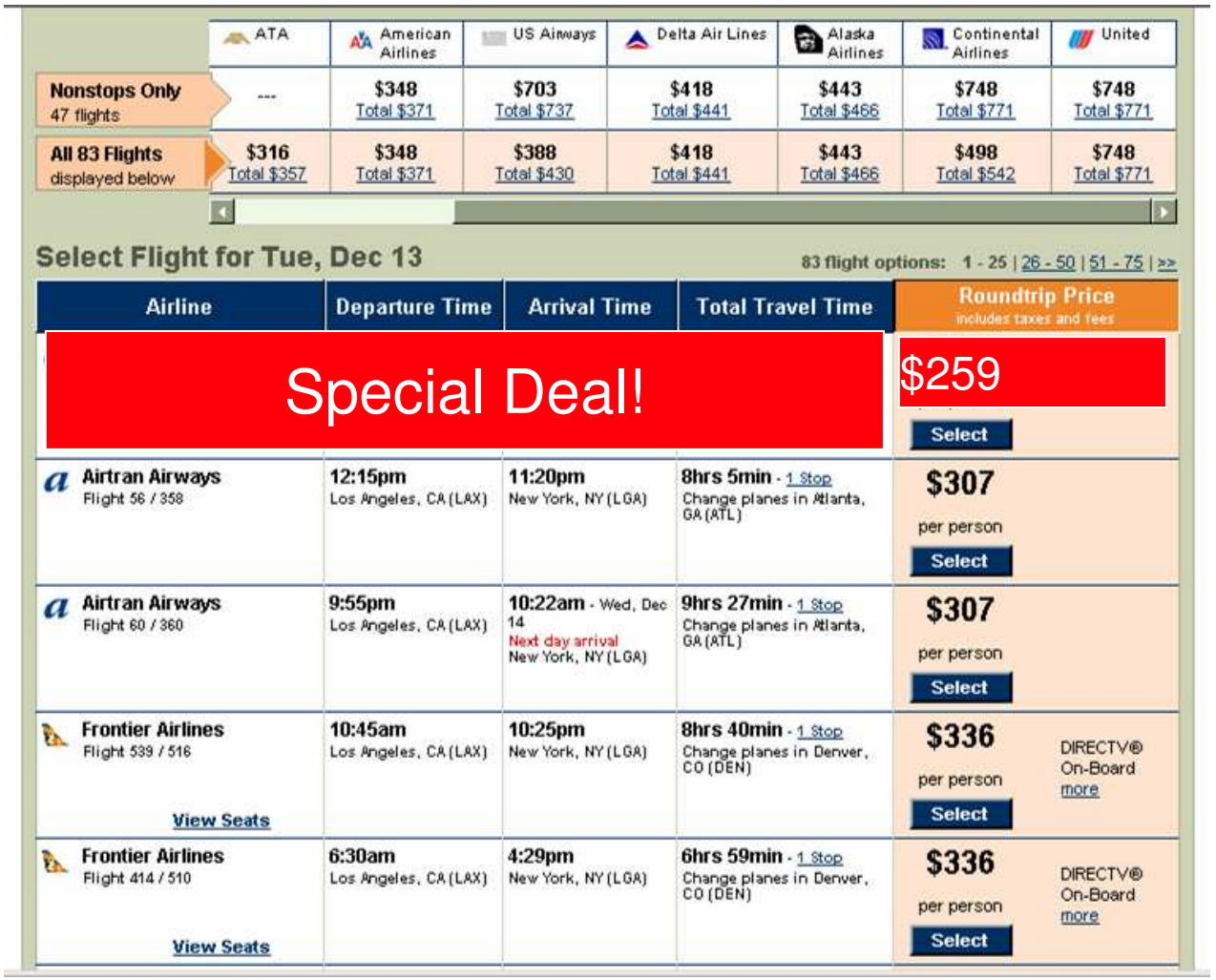
There Has Been Good Academic Work on the Network Optimization Problem



An efficient, workable solution has not been developed and implemented

Session Level Optimization Simplifies Modeling …



	ATA	American Airlines	US Airways	Delta Air Lines	Alaska Airlines	Continental Airlines	United
Nonstops Only 47 flights	---	$348 Total $371	$703 Total $737	$418 Total $441	$443 Total $466	$748 Total $771	$748 Total $771
All 83 Flights displayed below	$316 Total $357	$348 Total $371	$388 Total $430	$418 Total $441	$443 Total $466	$498 Total $542	$748 Total $771

Select Flight for Tue, Dec 13

83 flight options: 1 - 25 | 26 - 50 | 51 - 75 | >>

Airline	Departure Time	Arrival Time	Total Travel Time	Roundtrip Price (includes taxes and fees)	
Special Deal!				$259 Select	
Airtran Airways Flight 56 / 358	12:15pm Los Angeles, CA (LAX)	11:20pm New York, NY (LGA)	8hrs 5min - 1 Stop Change planes in Atlanta, GA (ATL)	$307 per person Select	
Airtran Airways Flight 60 / 360	9:55pm Los Angeles, CA (LAX)	10:22am - Wed, Dec 14 Next day arrival New York, NY (LGA)	9hrs 27min - 1 Stop Change planes in Atlanta, GA (ATL)	$307 per person Select	
Frontier Airlines Flight 539 / 516 View Seats	10:45am Los Angeles, CA (LAX)	10:25pm New York, NY (LGA)	8hrs 40min - 1 Stop Change planes in Denver, CO (DEN)	$336 per person Select	DIRECTV® On-Board more
Frontier Airlines Flight 414 / 510 View Seats	6:30am Los Angeles, CA (LAX)	4:29pm New York, NY (LGA)	6hrs 59min - 1 Stop Change planes in Denver, CO (DEN)	$336 per person Select	DIRECTV® On-Board more

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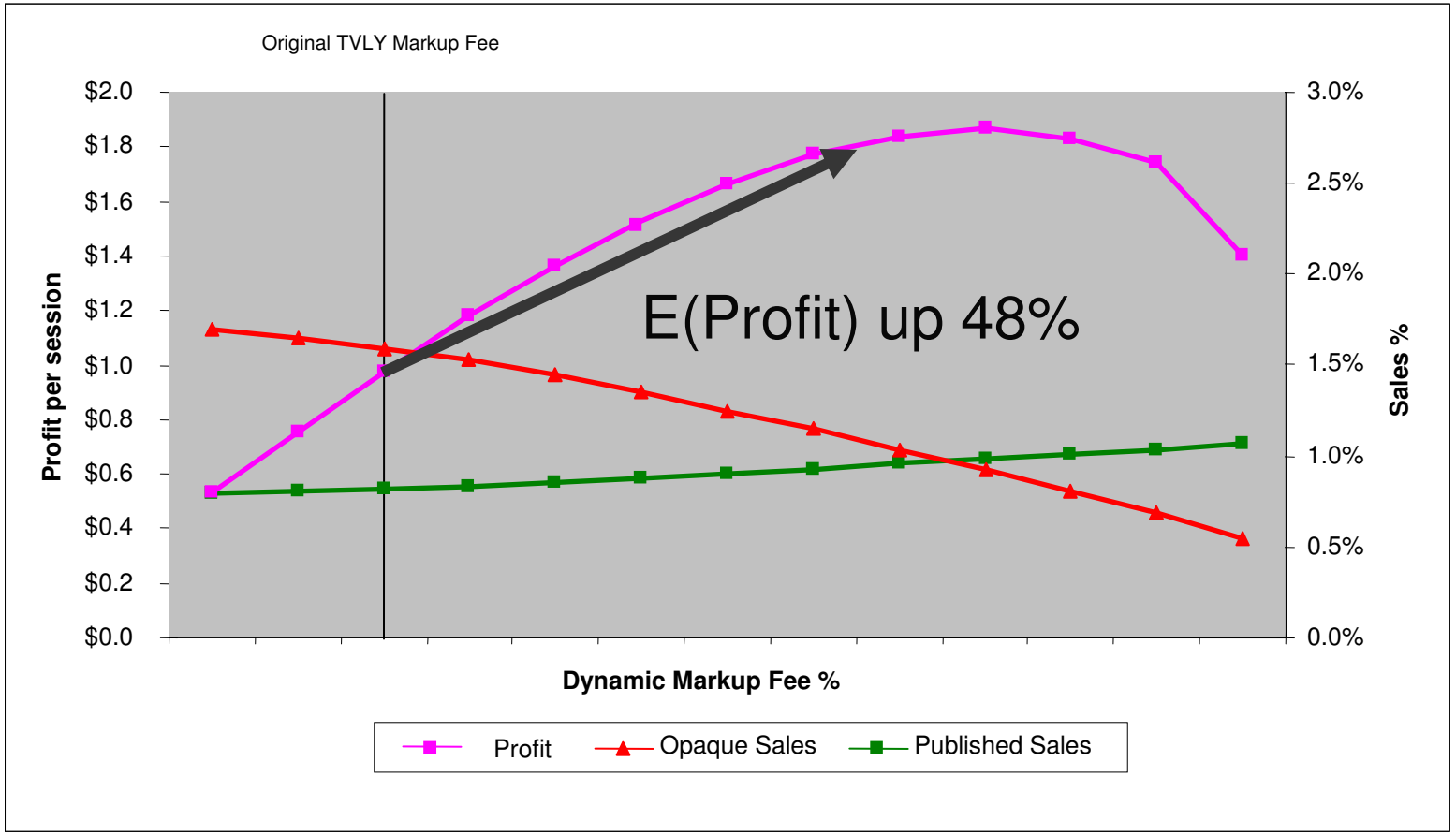
… and Improves Performance



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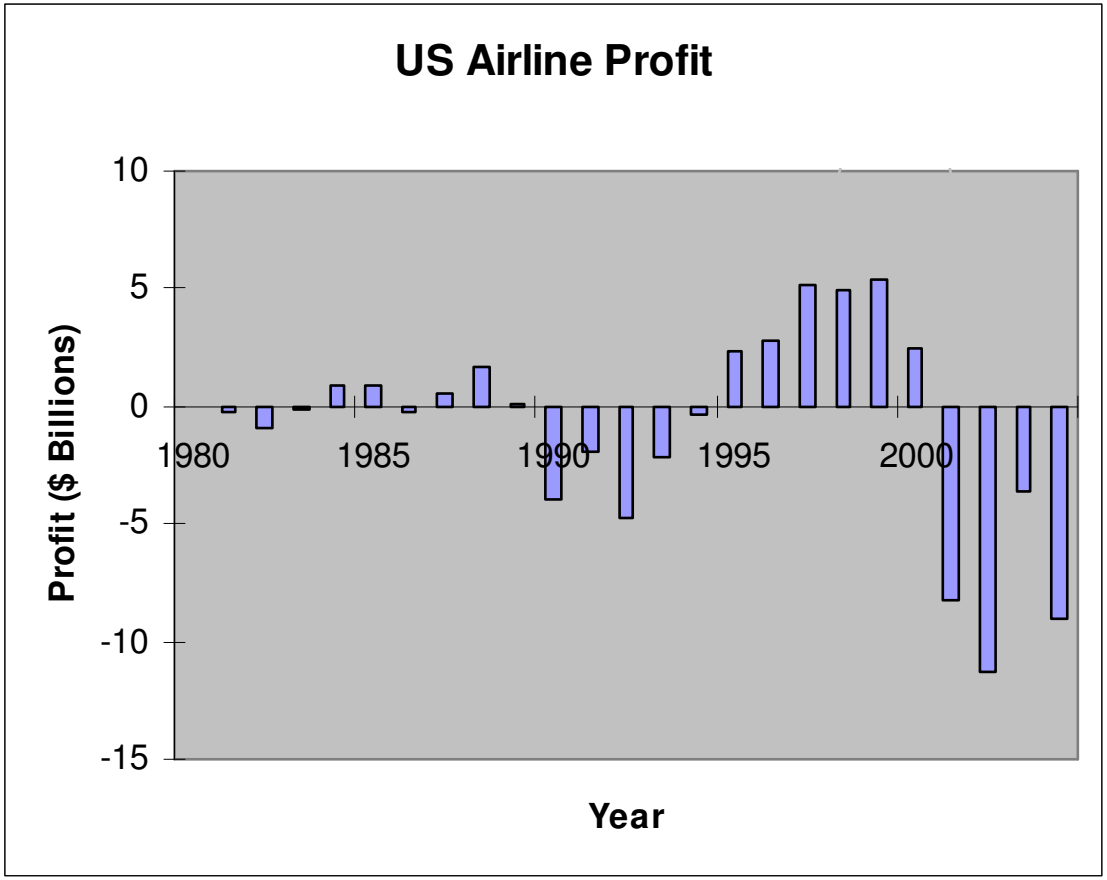
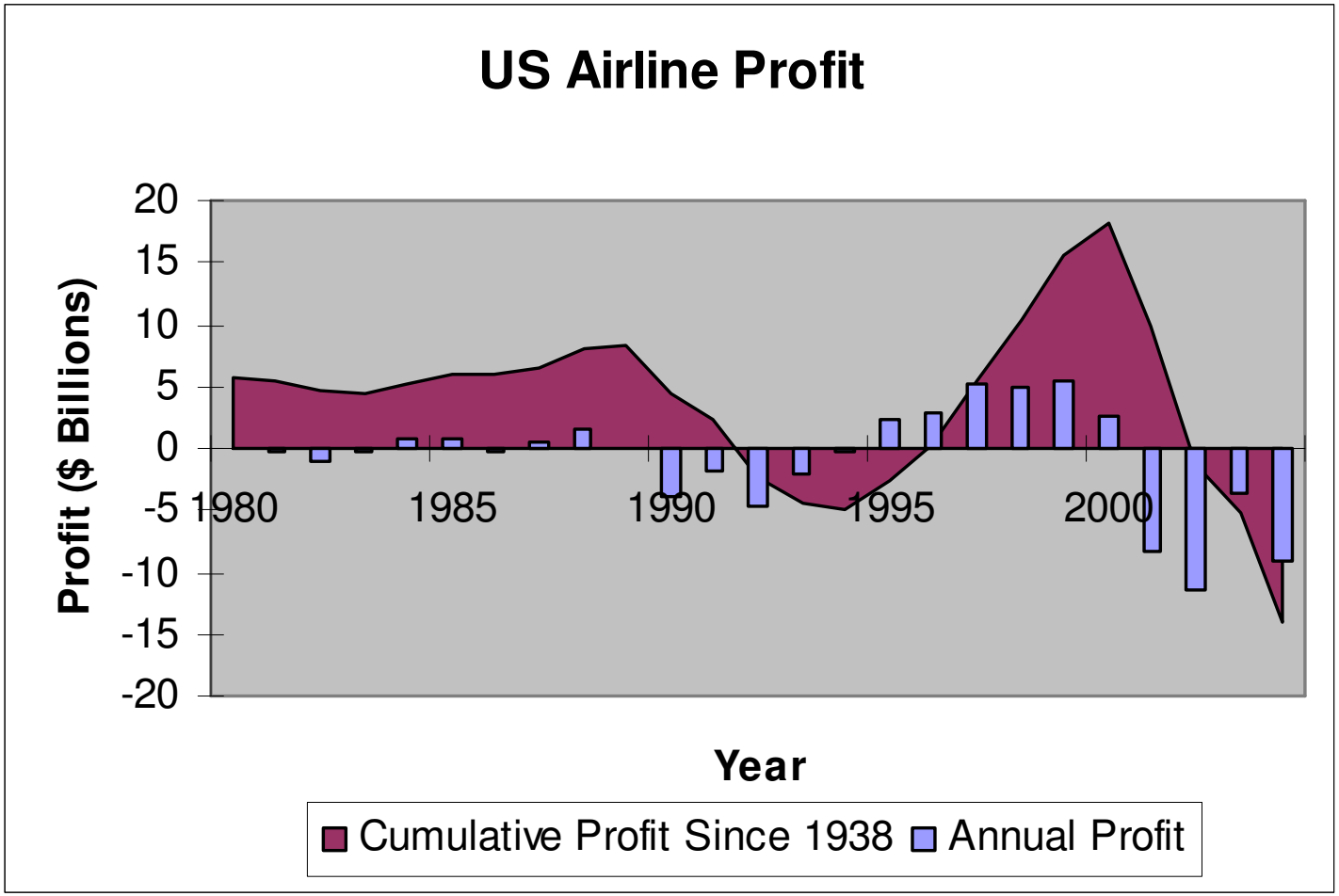
RM in the Current Airline Environment

Since Deregulation, the Amplitude of the Profit Cycle has Increased

- Commoditization of airline products
- Disparities in costs
- Reduction of segmentation
- Transparency of price
- Bankruptcy protection
- Threat of terrorism



Since 1938 the Industry has Net Losses



How can RM Help Airlines Get Better?

- Increase our knowledge of customers
- Integrate decisions
- Improve value propositions

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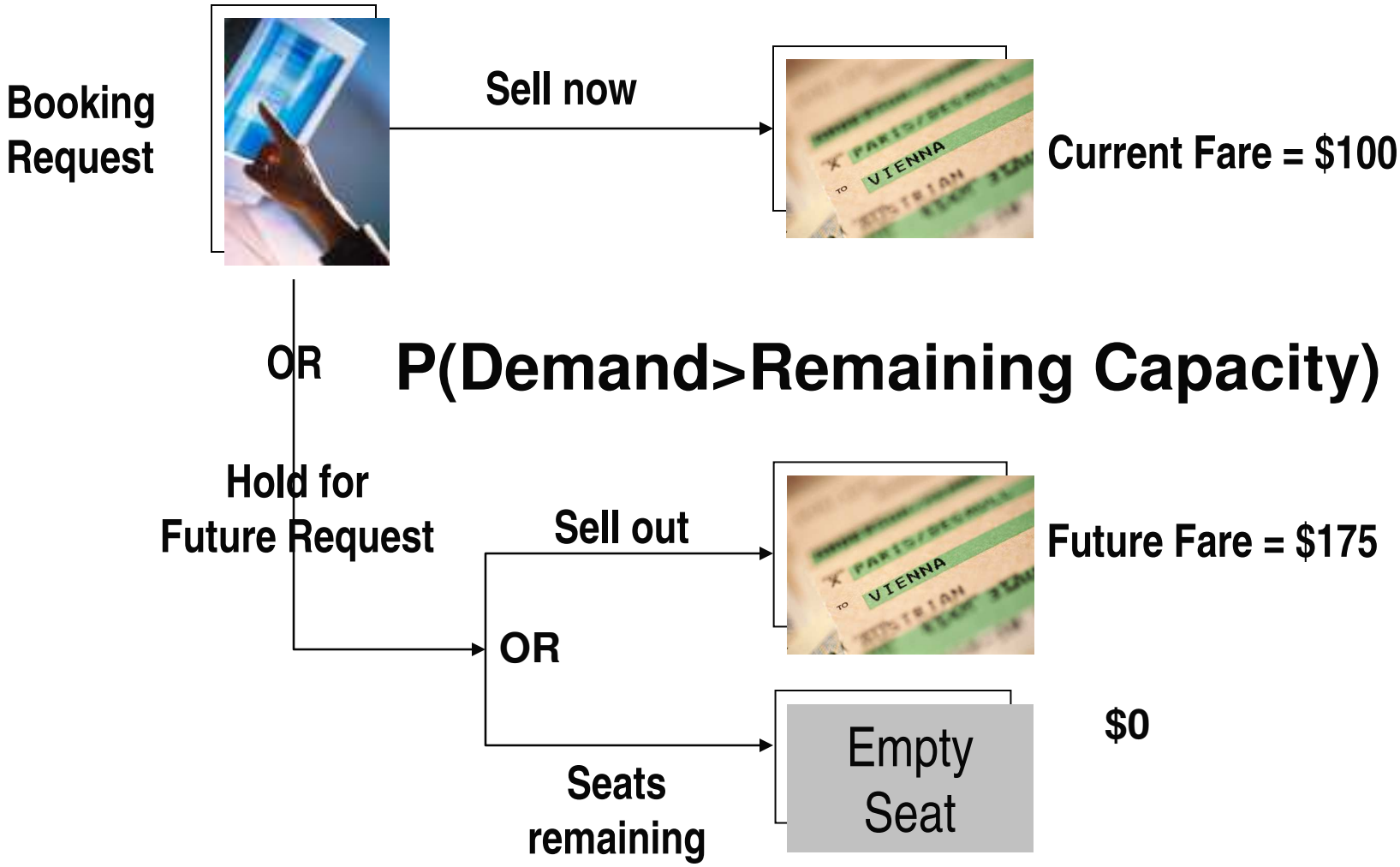
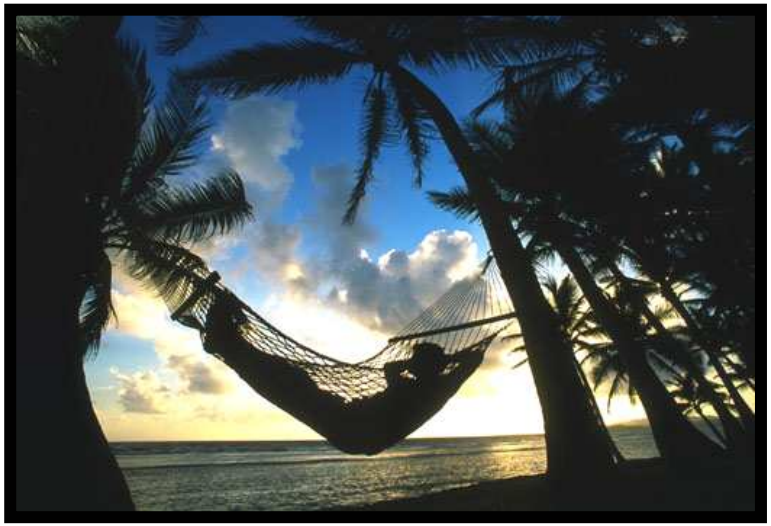
We Know a Lot About our Customers

Customer Knowledge has Supported Demand Forecasting



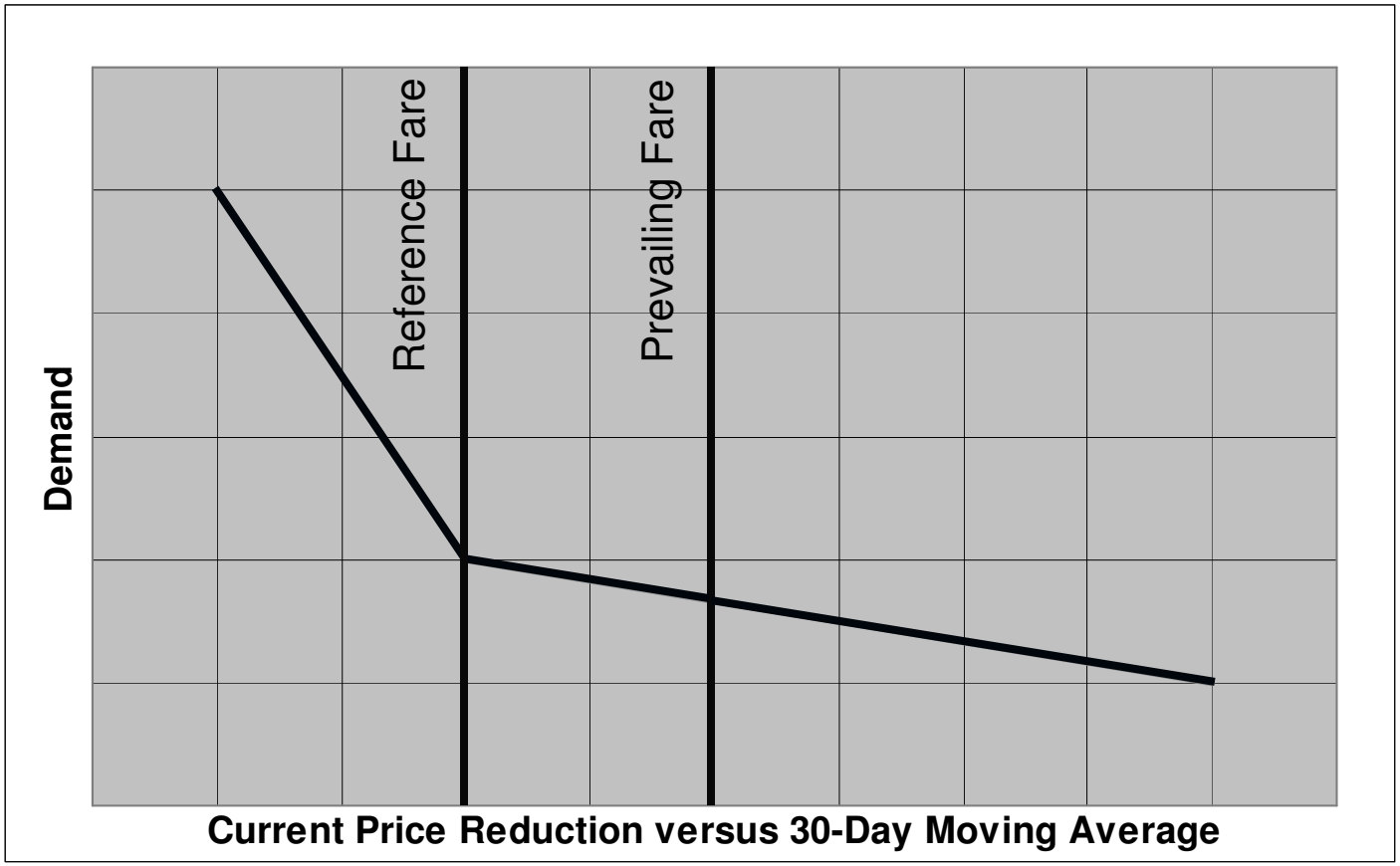
Customer Understanding Drives Relevance-based Marketing



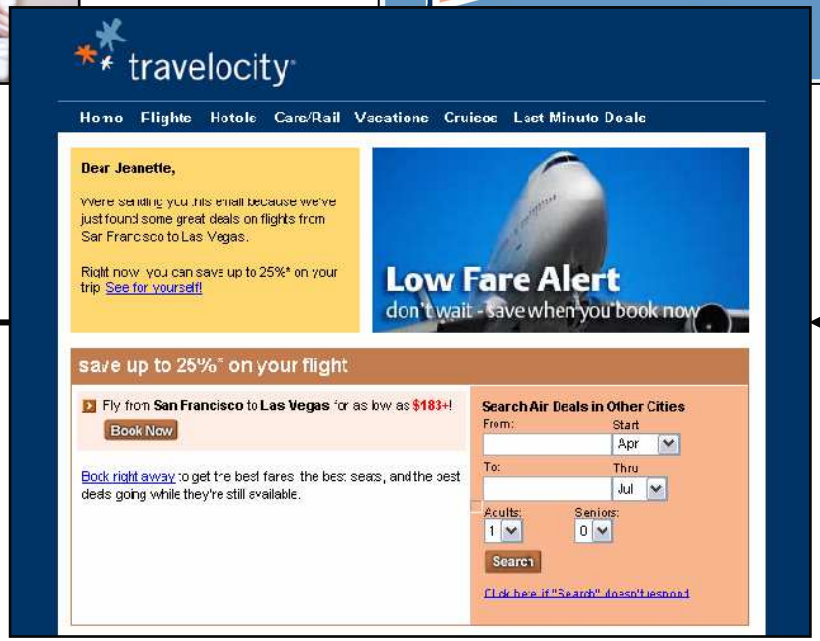
Nondiscretionary Demand
Low price sensitivity
Relatively constant demand

Discretionary Demand
High price sensitivity
Highly volatile demand

Relevance-based Marketing



… to Improve Email Campaign Effectiveness



Good Day To Buy
Determine Ref Fares
Check Current vs Ref Fares
Find Recent Shoppers
Create Email

How can RM Help the Airlines to Get Better?

- Increase our knowledge of customers
- **Integrate decisions**
- Improve value propositions

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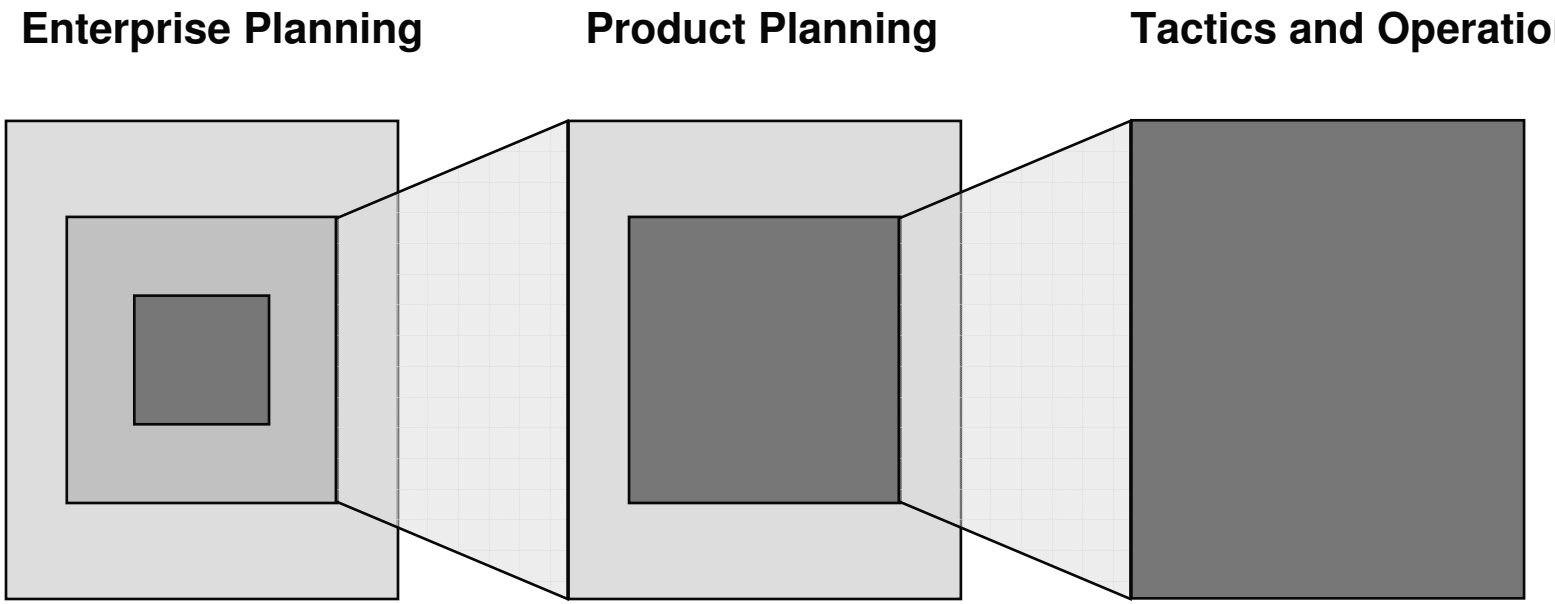
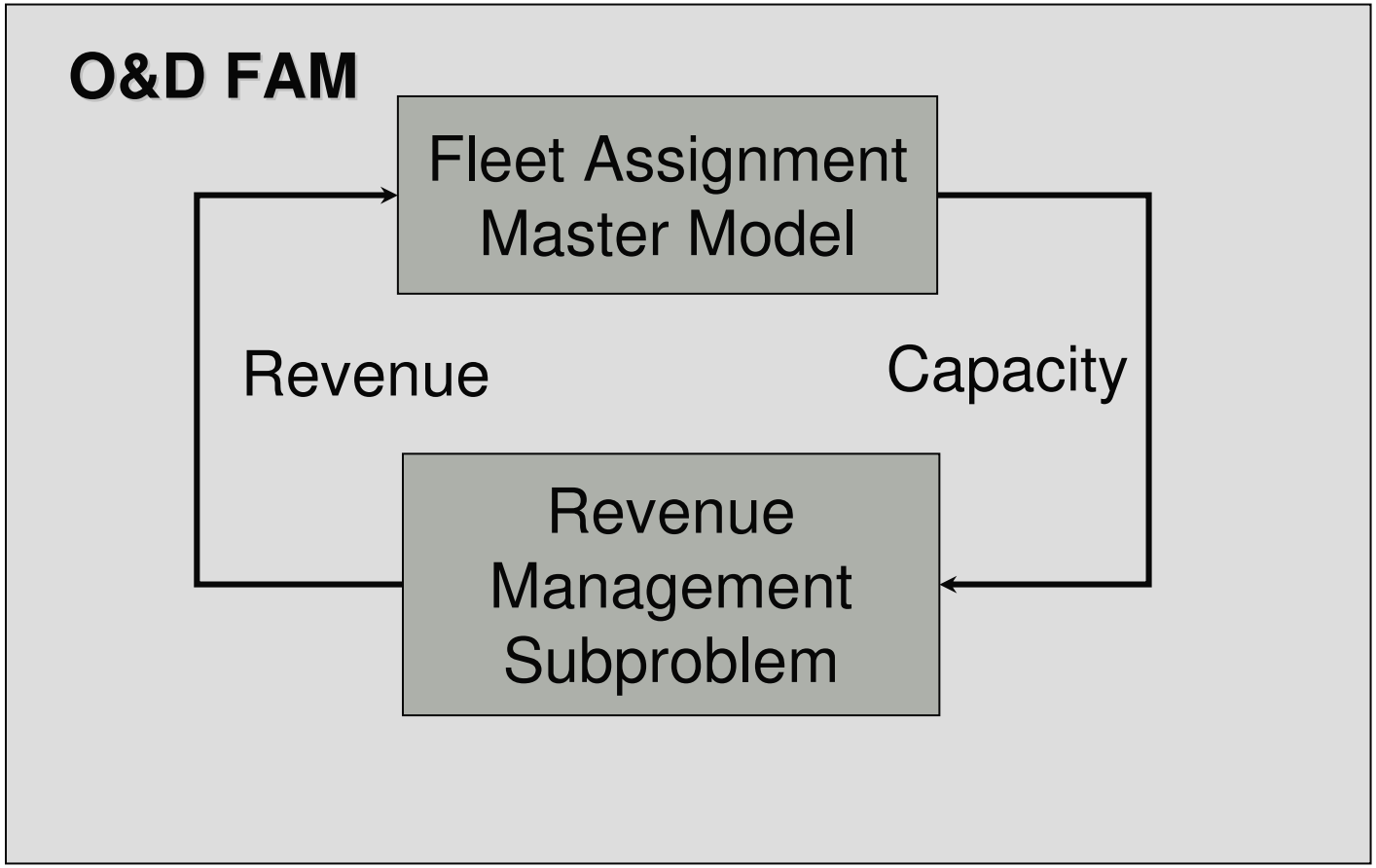
Airline Performance will Improve with Continuity in Objectives and Decisions



Better RM Modeling in Fleet Assignment Increases Airline Profit by 1-2 Margin Points



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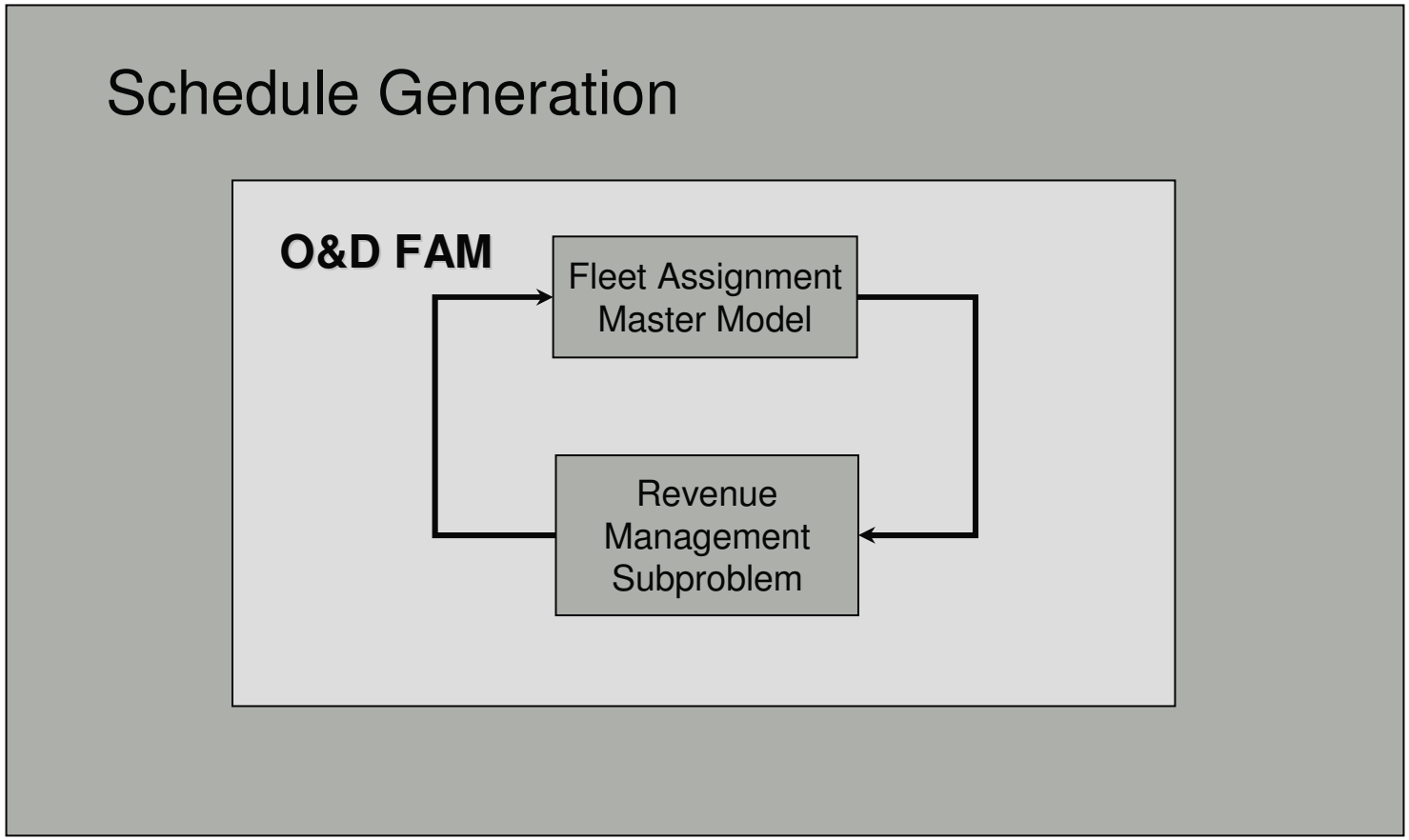
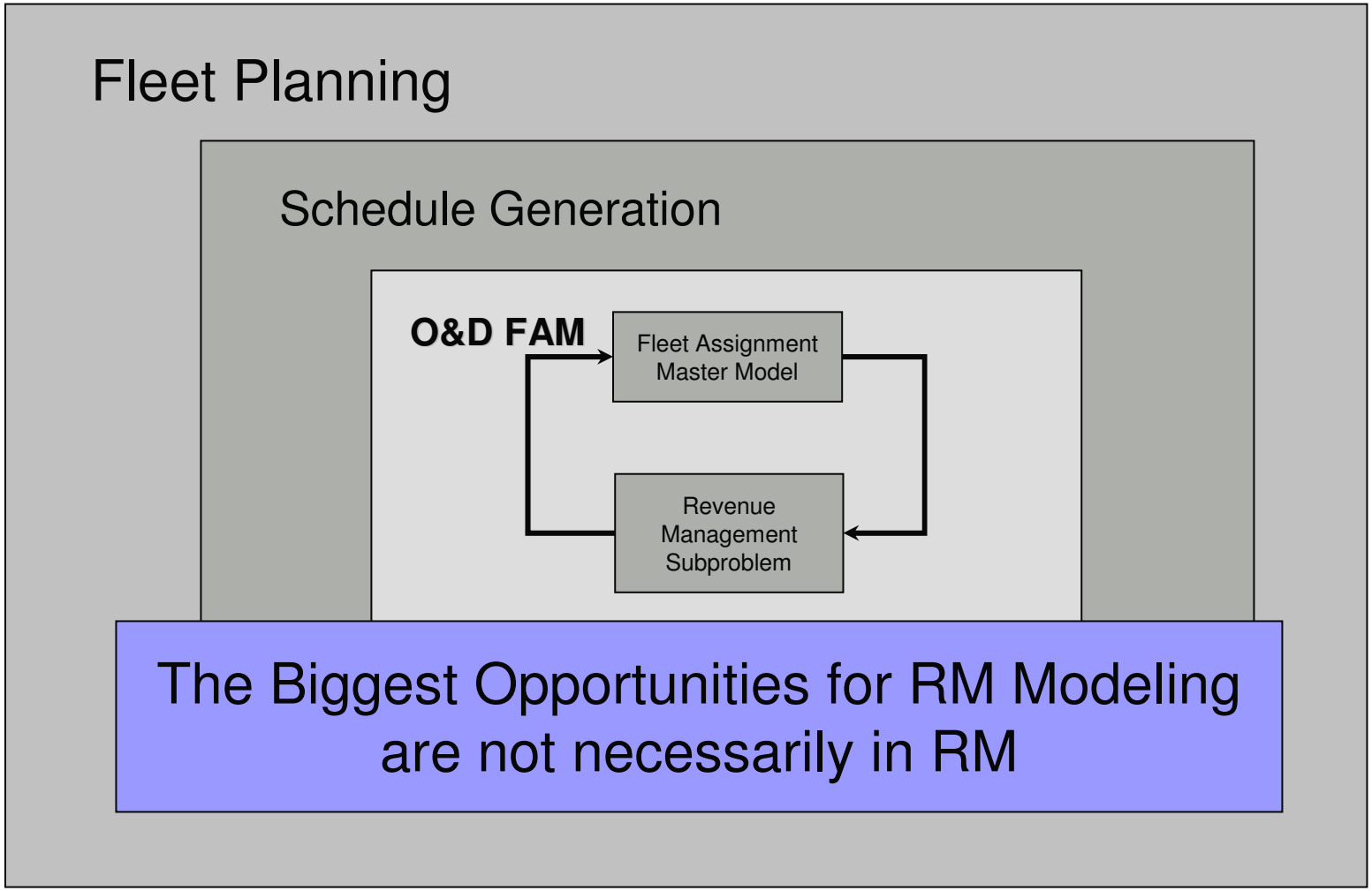
O&D FAM is a Sub-problem in Schedule Generation



Which is a Sub-problem for Fleet Planning



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How can RM Help the Airlines to Get Better?

- Increase our knowledge of customers
- Integrate decisions
- **Improve value propositions**

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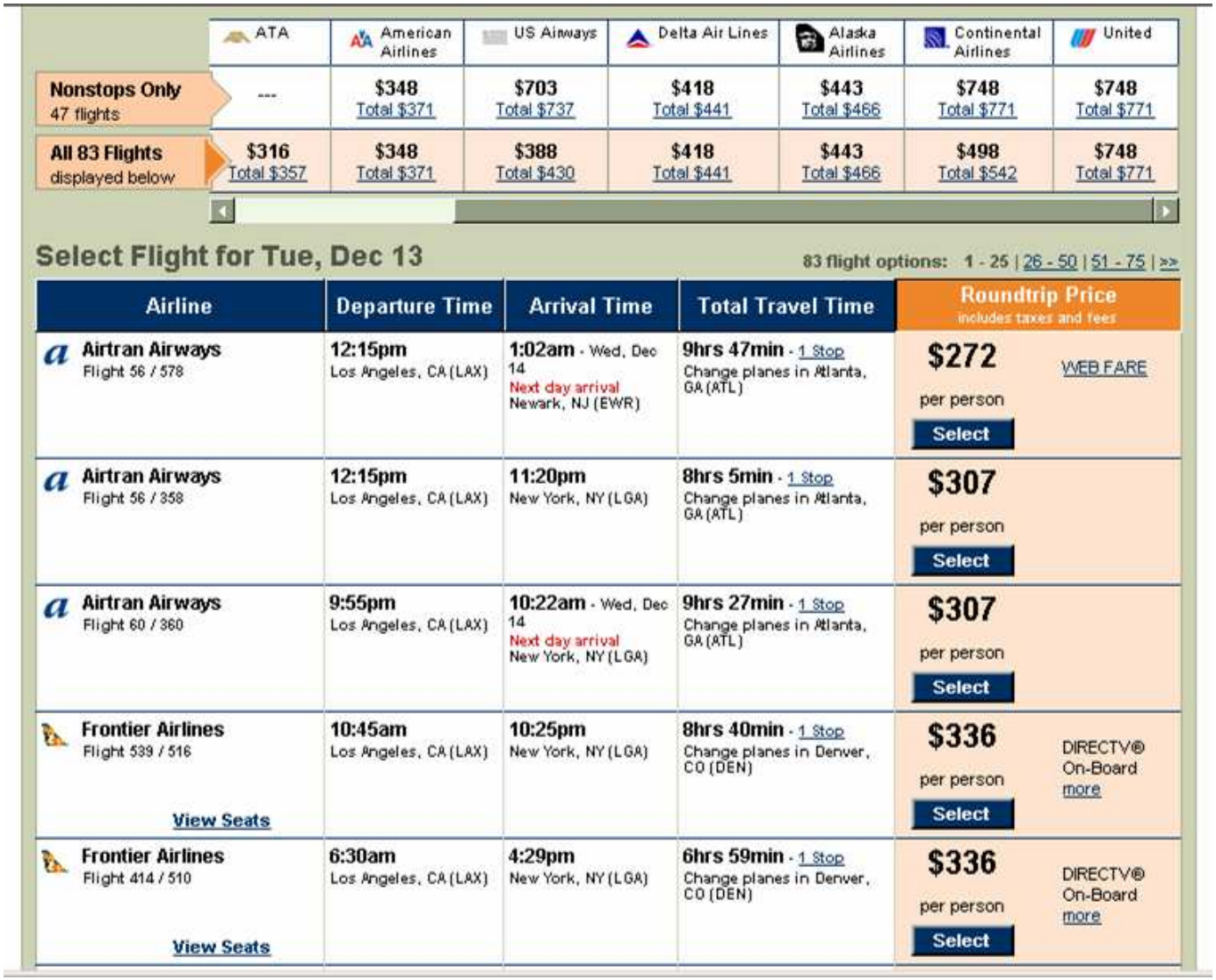
Value Proposition for Major Airlines
Barely Adequate Service @$0.15 - $0.30 /Seat-Mile



	ATA	American Airlines	US Airways	Delta Air Lines	Alaska Airlines	Continental Airlines	United
Nonstops Only 47 flights	---	$348 Total $371	$703 Total $737	$418 Total $441	$443 Total $466	$748 Total $771	$748 Total $771
All 83 Flights displayed below	$316 Total $357	$348 Total $371	$388 Total $430	$418 Total $441	$443 Total $466	$498 Total $542	$748 Total $771

Select Flight for Tue, Dec 13

83 flight options: 1 - 25 | 26 - 50 | 51 - 75 | >>

Airline	Departure Time	Arrival Time	Total Travel Time	Roundtrip Price (includes taxes and fees)	
Airtran Airways Flight 56 / 578	12:15pm Los Angeles, CA (LAX)	1:02am - Wed, Dec 14 Next day arrival Newark, NJ (EWR)	9hrs 47min - 1 Stop Change planes in Atlanta, GA (ATL)	$272 per person Select	WEB FARE
Airtran Airways Flight 56 / 358	12:15pm Los Angeles, CA (LAX)	11:20pm New York, NY (LGA)	8hrs 5min - 1 Stop Change planes in Atlanta, GA (ATL)	$307 per person Select	
Airtran Airways Flight 60 / 360	9:55pm Los Angeles, CA (LAX)	10:22am - Wed, Dec 14 Next day arrival New York, NY (LGA)	9hrs 27min - 1 Stop Change planes in Atlanta, GA (ATL)	$307 per person Select	
Frontier Airlines Flight 539 / 516 View Seats	10:45am Los Angeles, CA (LAX)	10:25pm New York, NY (LGA)	8hrs 40min - 1 Stop Change planes in Denver, CO (DEN)	$336 per person Select	DIRECTV® On-Board more
Frontier Airlines Flight 414 / 510 View Seats	6:30am Los Angeles, CA (LAX)	4:29pm New York, NY (LGA)	6hrs 59min - 1 Stop Change planes in Denver, CO (DEN)	$336 per person Select	DIRECTV® On-Board more

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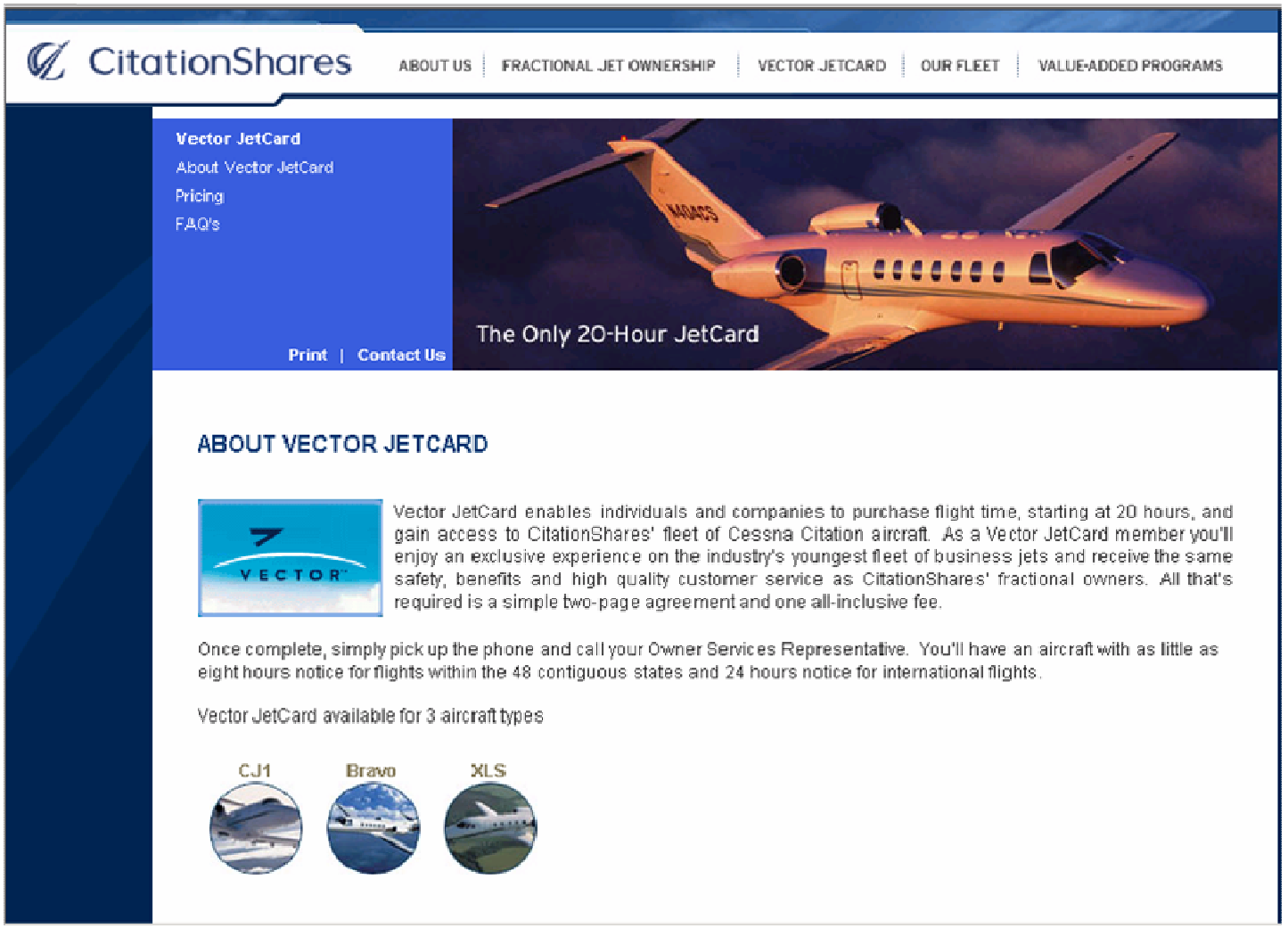
Improve Service > $1/Seat-Mile



Reduce Cost: $0/Seat-Mile

Ryanair have just announced their ***free flights*** offer… available on over 100 routes on Ryanair's European network … the airline is giving away some 500,000 free flights … subject, of course, to the usual taxes and charges.

They are not Kidding

This is Not a Promotion, It's a New Business Model

Fly From **London (Stansted)** £

Fares are exclusive of taxes fees & charges which do not exceed £15.20

	from		from		from
Oslo (Torp)	Free	**Szczecin**	Free	**Carcassonne**	1.29
Biarritz	Free	**La Rochelle**	Free	**Altenburg** (Leipzig)	1.29
Murcia (Alicante)	Free	**Montpellier**	Free	**Pisa** (Florence)	1.29
Frankfurt (Hahn)	Free	**PortAventura** (Reus)	Free	**Dublin**	1.29
Santander	Free			**Parma** NEW	1.79
Limoges	Free	**Rodez**	Free	**Friedrichshafen**	2.29
Zaragoza(Pyrenees)	Free	**Reus** (Barcelona)	Free	**Kerry**	2.29
Glasgow (Prestwick)	Free	**Karlsruhe-Baden**	0.29	**Salzburg**	2.29
Granada	Free	**Hamburg** (Lübeck)	0.29	**Derry**	2.29
Linz	Free	**Milan** (Bergamo)	0.29	**Graz**	2.29
Trieste	Free	**Malmo** (Sturup)	0.29	**Cork**	2.99
Nantes (Brittany)	Free	**Gothenburg**	0.29	**Krakow**	3.19
Gdañsk	Free	**Newquay**	0.29	**Kaunas**	3.19
Perpignan	Free			**Riga**	3.29
Blackpool	Free	**Rome** (Ciampino)	1.29	**Brno**	3.29
Grenoble Lyon	Free	**Ancona**	1.29	**Lodz**	3.29
St. Etienne (Lyon)	Free	**Bari**	1.29	**Rzeszów**	3.29
Haugesund	Free	**Palermo**	1.29	**Poznan**	3.29
Pau (Pyrenees)	Free	**Berlin** (Schonefeld)	1.29	**Seville**	4.29
Toulon	Free	**Turin**	1.29	**Jerez**	4.29
Poitiers	Free	**Pescara**	1.29	**Lamezia** NEW	4.79
Tours Loire Valley	Free	**Stockholm** (NYO)	1.29	**Balaton** NEW	4.79
Girona (Barcelona)	Free	**Brindisi**	1.29	**Vitoria/Gasteiz** NEW	4.79
Esbjerg	Free	**Bologna** (Forli)	1.29		
		Santiago De Comp.	1.29		

What are the RM Opportunities when fare is no longer a significant part of the value proposition?

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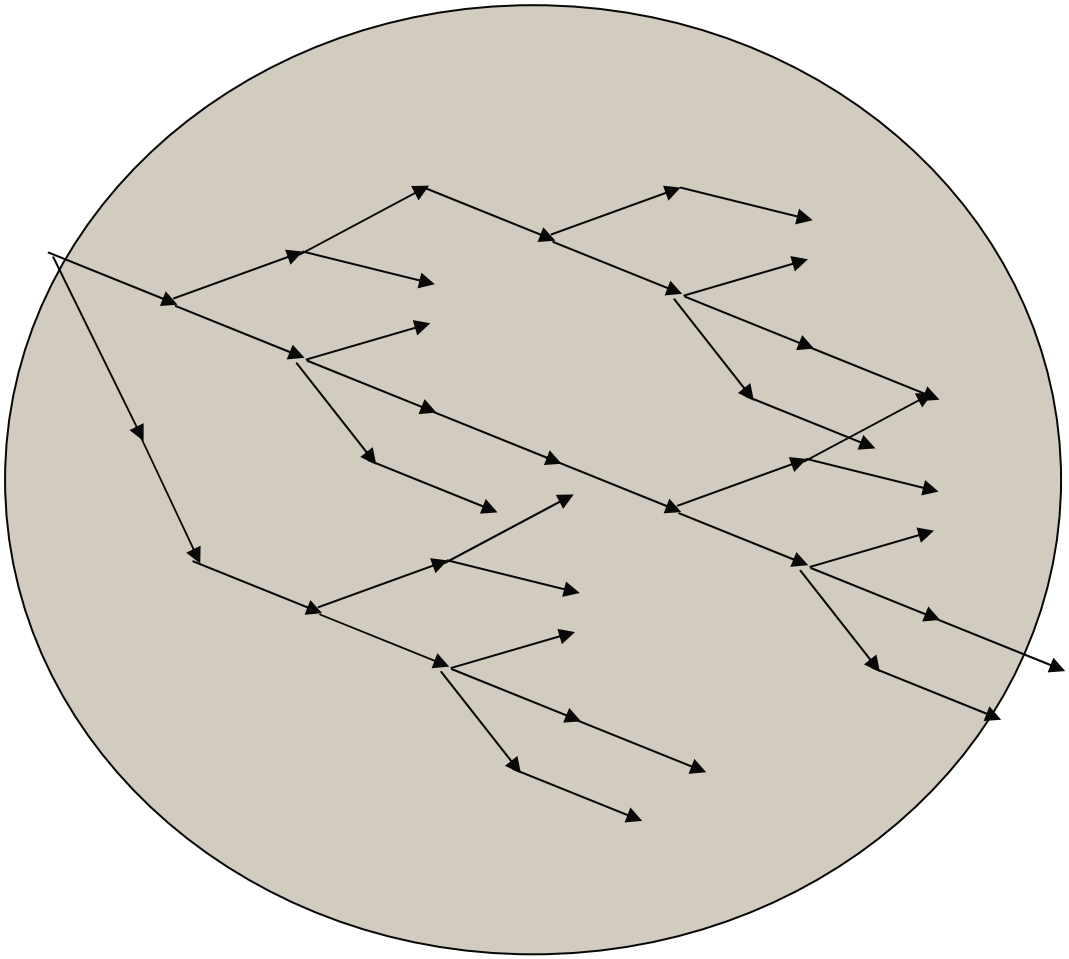
Robust Planning and Marketing: Integration of RM, Planning and Operations

- **Airline operations are subject to disruptions due to**
  - Weather
  - Mechanical problems
  - Labor
  - ATC
- **Delays and cancellations propagate through the network**



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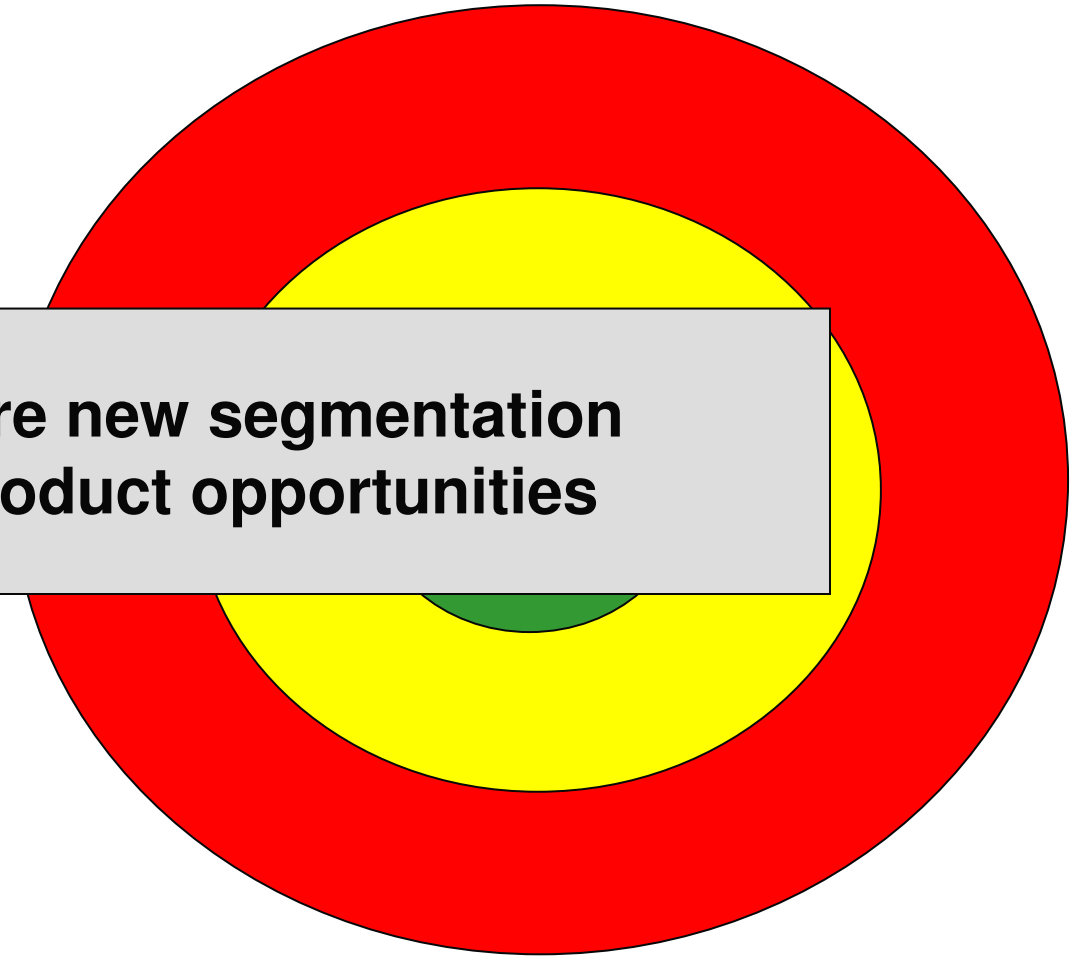
Degradable Scheduling and Operations Segmentation by Reliability

- **Airlines can reduce cancellation and delay propagation**
  - Layer the schedule
  - Minim
    aircra
    passe
    layers
- **Core layers have significantly greater reliability than current operations**



There are new segmentation and product opportunities

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Future RM Modeling Directions

RM Opportunities

For each flight leg, $i \in L$

For each fleet $f \in F$

Find min bid price, $\lambda^{k}_{f,i}$

such that $| cap_f - \sum_{p \in i} alloc^k_p | \le \varepsilon$, $alloc^k_p = \Gamma^{-1}(1-(\lambda^{k}_{f,i} + \sum_{j \ne i, j \ni p} \lambda^{k}_{j}) / rev_p)$

For each passenger type $p \in l$, sum leg revenue:

$rev^k_{f,i} += proratedLegRev_{p,i} E(traf_p \mid Dmd_p, alloc^k_p)$

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Likely Aspects of Future RM Processes

- **Use of better data**
  - Shopping data (request, response, action) is becoming available
  - Visibility to previously unobservable features (spill, recapture)
- **Redefinition of forecasting**
  - Customer choice models
  - Include impacts of schedule, price and availability
  - Fewer, more consistent forecasts
  - Linked with forecasts of Scheduling and Pricing
  - Reduce impact of forecast errors

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Likely Aspects of Future RM Processes

- **Increased scope of optimization**
  - Optimize price and allocations continuously prior to departure
  - Incorporate features of customer behavior (upsell and recapture) directly into optimization models and controls
  - Models for use in up-line processes
- **Simplification of systems and operations**
  - Event-driven data collection and updates
  - Sparse data techniques

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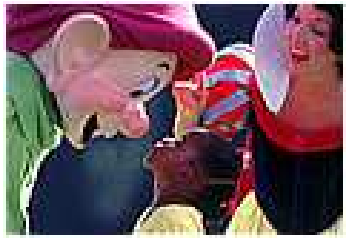
Final Thoughts

Technology has Reduced the Barriers for New RM Applications



RM Success Criteria

- Senior management support
- Time and resources
- Performance measurement
- Humility – it is much easier to make things worse than better

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Revenue Management Resources

- **"Revenue Management: Research Overview and Prospects"**
  - Jeff McGill, Garrett van Ryzin
  - *Transportation Science*, May 1999
- **"Revenue Management and E-Commerce"**
  - Andy Boyd, Ioana Bilegan
  - *Management Science*, October 2003
- ***Journal of Revenue and Pricing Management***
- **INFORMS Revenue Management Section**
- **AGIFORS Revenue Management Study Group**

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Thank you

The End

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