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Network Revenue Management: Origin-Destination Control

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Presentation Outline

- **Need for Network Revenue Management**
  - Limitations of Fare Class Yield Management
  - What is O-D Control?
- **Basic O-D Control Mechanisms:**
  - Revenue Value Buckets
  - Displacement Adjusted Virtual Nesting
  - Bid Price Control
  - System Components and Alternatives
- **Examples of O-D Simulation Results**

Background: Fare Class Control

- **Vast majority of world airlines still practice "fare class control":**
  - High-yield ("full") fare types in top booking classes
  - Lower yield ("discount") fares in lower classes
  - Designed to maximize yields, not total revenues

- **Seats for connecting itineraries must be available in same class across all flight legs:**
  - Airline cannot distinguish among itineraries
  - "Bottleneck" legs can block long haul passengers

Yield-Based Fare Class Structure (Example)

BOOKING CLASS	FARE PRODUCT TYPE
Y	Unrestricted "full" fares
B	Discounted one-way fares
M	7-day advance purchase round-trip excursion fares
Q	14-day advance purchase round-trip excursion fares
V	21-day advance purchase or special promotional fares

Leg-Based Class Availability

FLIGHT LEG INVENTORIES

LH 100	NCE-FRA
CLASS	AVAILABLE
Y	32
B	18
M	0
Q	0
V	0

LH 200	FRA-HKG
CLASS	AVAILABLE
Y	142
B	118
M	97
Q	66
V	32

LH 300	FRA-JFK
CLASS	AVAILABLE
Y	51
B	39
M	28
Q	17
V	0

ITINERARY/FARE AVAILABILITY

NCE/FRA	LH 100	Y	B			
NCE/HKG	LH 100	Y	B			
	LH 200	Y	B	M	Q	V
NCE/JFK	LH 100	Y	B			
	LH 300	Y	B	M	Q	

Leg Class Control Does Not Maximize Total Network Revenues

(A) SEAT AVAILABILITY: **SHORT HAUL BLOCKS LONG HAUL**

NCE/FRA	
CLASS	FARE (OW)
Y	$450
B	$380
M	$225
Q	$165
V	$135

NCE/HKG	(via FRA)
CLASS	FARE (OW)
Y	$1415
B	$975
M	$770
Q	$590
V	$499

NCE/JFK	(via FRA)
CLASS	FARE (OW)
Y	$950
B	$710
M	$550
Q	$425
V	$325

(B) SEAT AVAILABILITY: **LOCAL VS. CONNECTING PASSENGERS**

NCE/FRA	
CLASS	FARE (OW)
Y	$450
B	$380
M	$225
Q	$165
V	$135

FRA/JFK	
CLASS	FARE (OW)
Y	$920
B	$670
M	$515
Q	$385
V	$315

NCE/JFK	(via FRA)
CLASS	FARE (OW)
Y	$950
B	$710
M	$550
Q	$425
V	$325

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The O-D Control Problem

- **Revenue maximization over a network of connecting flights requires two strategies:**
  - **(1) Increase availability to high-revenue, long-haul passengers, regardless of yield;**
  - **(2) Prevent long-haul passengers from displacing high-yield short-haul passengers on full flights.**

- **Revenue benefits of (1) outweigh risks of (2):**
  - **Probability of <u>both</u> connecting flights being fully booked is low, relative to other possible outcomes**

What is O-D Control?

- The capability to respond to different O-D requests with different seat availability.

- Can be implemented in a variety of ways:
  - Revenue value buckets ("greedy approach")
  - EMSR heuristic bid price
  - Displacement adjusted virtual nesting
  - Network "optimal" bid price control

- All of the above can increase revenues, but each one has implementation trade-offs.

Revenue Value Bucket Concept

- Fixed relationship between fare type and booking class is abandoned:
  - Booking classes ("buckets") defined according to revenue value, regardless of fare restrictions
  - Each itinerary/fare type (i.e.., "ODF") assigned to a revenue value bucket on each flight leg
  - ODF seat availability depends on value buckets
- Value concept can be implemented within existing classes or through "virtual" classes

Value Bucket Implementation

- **Within Existing Booking Classes:**
  - Fare codes need to be re-published according to revenue value; no changes to inventory structure
  - Does not require seamless CRS links, but can be confusing to travel agents and consumers

- **Development of Virtual Inventory Classes:**
  - Substantial cost of new inventory structure and mapping functions to virtual classes
  - CRS seamless availability links are essential

Stratified Bucketing by Revenue Value

ORIGINAL PUBLISHED FARES/CLASSES

NCE/FRA	
CLASS	FARE (OW)
Y	$450
B	$380
M	$225
Q	$165
V	$135

NCE/HKG	(via FRA)
CLASS	FARE (OW)
Y	$1415
B	$975
M	$770
Q	$560
V	$499

NCE/JFK	(via FRA)
CLASS	FARE (OW)
Y	$950
B	$710
M	$550
Q	$425
V	$325

STRATIFIED FARES BY ODF VALUE

STRATIF. BUCKET	REVENUE RANGE	MAPPING OF O-D MARKETS/CLASSES	
Y	800 +	Y NCEHKG Y NCEJFK	B NCEHKG
B	560-799	M NCEHKG B NCEJFK	Q NCEHKG
M	440-559	V NCEHKG Y NCEFRA	M NCEJFK
Q	300-439	B NCEFRA V NCEJFK	Q NCEJFK
V	0-299	M NCEFRA V NCEFRA	Q NCEFRA

Virtual Class Mapping by ODF Revenue Value

FARE VALUES BY ITINERARY

NCE/FRA	
CLASS	FARE (OW)
Y	$450
B	$380
M	$225
Q	$165
V	$135

NCE/HKG	(via FRA)
CLASS	FARE (OW)
Y	$1415
B	$975
M	$770
Q	$590
V	$499

NCE/JFK	(via FRA)
CLASS	FARE (OW)
Y	$950
B	$710
M	$550
Q	$425
V	$325

MAPPING OF ODFs ON NCE/FRA LEG TO VIRTUAL VALUE CLASSES

VIRTUAL CLASS	REVENUE RANGE	MAPPING OF O-D MARKETS/CLASSES	
1	1200 +	Y NCEHKG	
2	900-1199	B NCEHKG	Y NCEJFK
3	750-899	M NCEHKG	
4	600-749	B NCEJFK	
5	500-599	Q NCEHKG	M NCEJFK
6	430-499	V NCEHKG	Y NCEFRA
7	340-429	B NCEFRA	Q NCEJFK
8	200-339	V NCEJFK	M NCEFRA
9	150-199	Q NCEFRA	
10	0 - 149	V NCEFRA	

Value Bucket O-D Control

- **Allows O-D control with existing RM system:**
  - Data collection and storage by leg/value bucket
  - Forecasting and optimization by leg/value bucket
  - Different ODF requests get different availability

- **But also has limitations:**
  - Re-bucketing of ODFs disturbs data and forecasts
  - Leg-based optimization, not a network solution
  - Can give too much preference to long-haul passengers (i.e..., "greedy" approach)

Displacement Cost Concept

- **Actual value of an ODF to network revenue on a leg is less than or equal to its total fare:**
  - Connecting passengers can displace revenue on down-line (or up-line) legs
- **How to determine network value of each ODF for O-D control purposes?**
  - Network optimization techniques to calculate displacement cost on each flight leg
  - Leg-based EMSR estimates of displacement

Value Buckets with Displacement

- **Given estimated down-line displacement, ODFs are mapped based on network value:**
  - Network value on Leg 1 = Total fare minus sum of down-line leg displacement costs
  - Under high demand, availability for connecting passengers is reduced, locals get more seats

- **Revision of displacement costs is an issue:**
  - Frequent revisions capture demand changes, but ODF re-mapping can disrupt bucket forecasts

Alternative Mechanism: Bid Price

- **Under value bucket control, accept ODF if its network value falls into an available bucket:**

  Network Value > Value of Last Seat on Leg; or

  Fare - Displacement > Value of Last Seat

- **Same decision rule can be expressed as:**

  Fare > Value of Last Seat + Displacement, or

  Fare > Minimum Acceptable "Bid Price" for ODF

- **Bid Prices and Value Buckets are simply two different O-D control mechanisms.**

O-D Bid Price Control

- **Much simpler inventory control mechanism than virtual buckets:**
  - Simply need to store bid price value for each leg
  - Evaluate ODF fare vs. itinerary bid price at time of availability request
  - Must revise bid prices frequently to prevent too many bookings of ODFs at current bid price

- **Bid prices can be calculated with network optimization tools or leg-based heuristics**

Example: Bid Price Control

A-------B-------C-------D

- Given leg bid prices

A-B: $35 B-C: $240 C-D: $160

- Availability for O-D requests B-C:

	Bid Price = $240	Available?
Y	$440	Yes
M	$315	Yes
B	$223	No
Q	$177	No

A-B: $35 B-C: $240 C-D: $160

A-C	Bid Price = $275	Available?
Y	$519	Yes
M	$374	Yes
B	$292	Yes
Q	$201	No

A-D	Bid Price = $435	Available?
Y	$582	Yes
M	$399	No
B	$322	No
Q	$249	No

Network vs. Heuristic Models

- **Estimates of displacement costs and bid prices can be derived using either approach:**
  - **Most O-D RM software vendors claim "network optimal" solutions possible with their product**
  - **Most airlines lack detailed data and face practical constraints in using network optimization models**
  - **Still substantial debate among researchers about which network O-D solution is "most optimal"**

- **Revenue gain, not optimality, is critical issue**

Use of Network Optimization Tools

- **To date, few airlines have implemented network optimization for dynamic O-D control:**
  - Lack of detailed historical ODF booking data
  - Technical and computational issues
  - Concerns about ODF demand forecasting accuracy (small numbers, high variance)
  - Difficult for RM analysts to interact with solutions

- **Recent RM developments have addressed first two issues, but other concerns remain.**

Leg-Based Heuristic Approaches

- **Several large airlines have implemented approximation models of network effects:**
  - **Estimates of displacement costs and/or bid prices based on leg/bucket EMSR calculations**
  - **Use existing inventory structure, databases, and RM system capabilities**
  - **Compatible with RM analyst work routines**

- **Low-risk approach to O-D revenue gains, as an intermediate step to network optimization**

EMSR Heuristic Bid Price Control

- **EMSR value of the last available seat on each leg is used in a bid price decision rule.**

- **Connecting ODF requests are accepted only if the total itinerary fare exceeds the current bid price:**
  - **Bid Price =MAX[EMSR1, EMSR2] + d*MIN[EMSR1, EMSR2], where $0 < d < 1.00$**

- **Local (1-leg) requests are controlled by EMSR fare class booking limits.**

O-D Control System Components

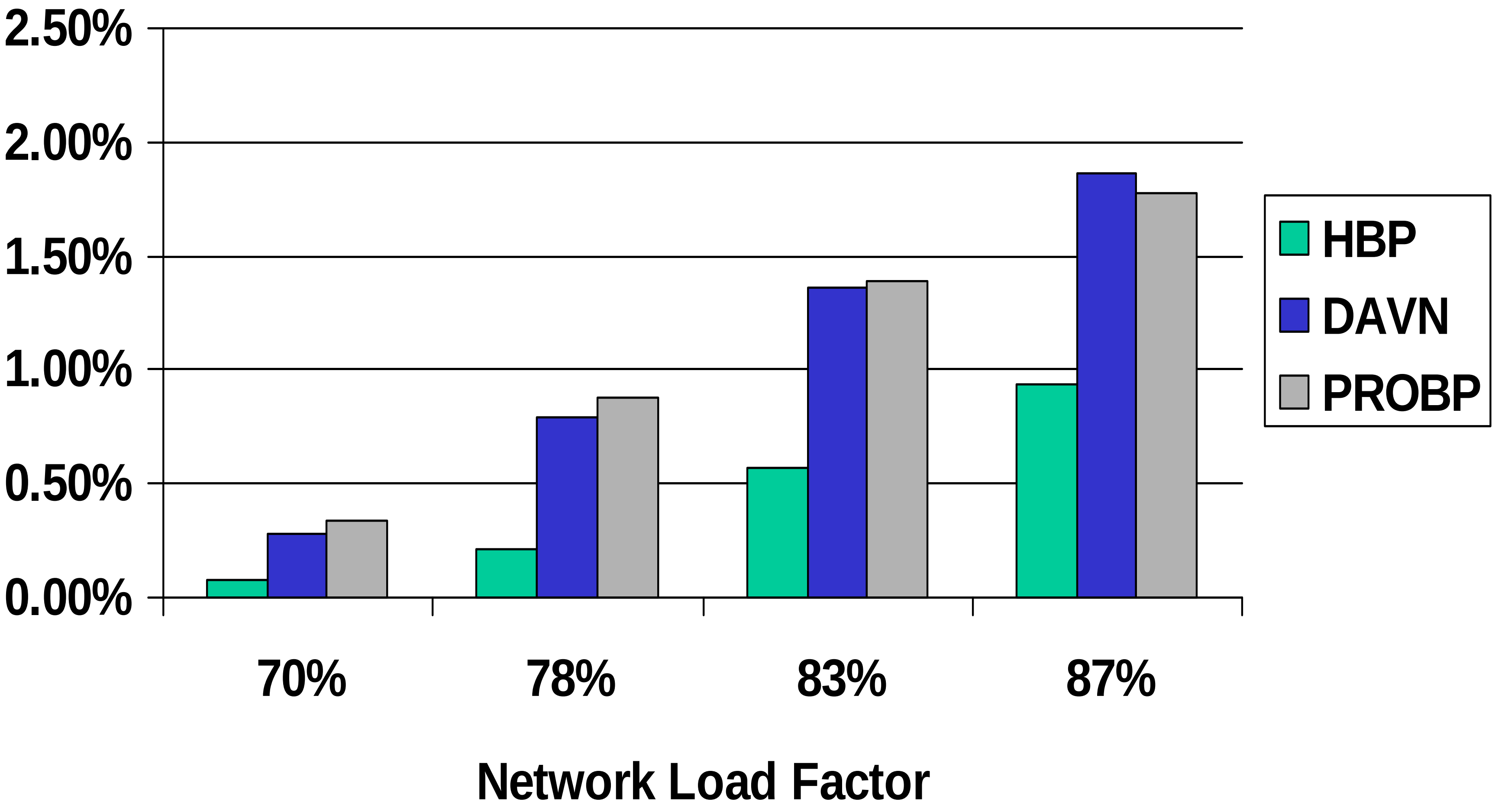
- **Much more than an optimization model:**
  - Database Requirements: Leg/bucket vs. ODF.
  - Forecasting Models: Level of detail to match data; detruncation and estimation methods.
  - Optimization Model: Leg-based or network tools; deterministic vs. probabilistic; dynamic programs
  - Control Mechanism: Booking classes vs. value buckets vs. bid price control.
- **Many effective combinations are possible:**
  - Revenue gain, not optimality, is the critical issue.

O-D Control System Alternatives

O-D Control System	Data and Forecasts	Optimization Model	Control Mechanism
Rev. Value Buckets	Leg/bucket	Leg EMSR	Leg/bucket Limits
Heuristic Bid Price	Leg/bucket	Leg EMSR	Bid Price for Connex only
Disp. Adjust. Value Bkts.	ODF	Network + Leg EMSR	Leg/bucket Limits
Network Bid Price	ODF	Network	O-D Bid Prices

O-D Revenue Gain Comparison

Airline A, O-D Control vs. Leg/Class RM



Potential for O-D Control

- **Simulations show potential O-D revenue gain:**
  - As much as 1-2% additional gain over leg/class control under ideal simulation conditions
- **Network characteristics affect O-D benefits:**
  - Substantial connecting traffic required
  - High demand factors on at least some feeder legs
  - Greater benefits with greater demand variability
- **CRS seamless availability links essential:**
  - Different responses to different ODF requests

O-D Implementation Questions

- **Can we forecast ODF demand by flight date?**
  - All network optimization methods require this input
- **Value buckets or bid price control?**
  - Affected by other airline functions and RM users
- **Which network optimization model?**
  - Trade-off costs, revenue gains, robustness issues
- **How will our RM business process change?**
  - Transition from leg/bucket controls to O-D traffic flows and network revenue values