Airline Revenue Management: Impacts of Fare Simplification on RM Systems

1.201 Transportation Systems Analysis: Demand & Economics

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Changing Fare Structures Worldwide

- **Major shifts in airline pricing strategies since 2000**
  - Growth of low-fare airlines with relatively unrestricted fares
  - Matching by legacy carriers to protect market share and stimulate demand
  - Increased consumer use of internet search engines to find lowest available fare options
  - Greater consumer resistance to complex fare structures and huge differentials between highest and lowest fares offered
- **Recent moves to "simplified" fares overlook the fact that pricing segmentation contributes to revenues:**
  - Fare simplification removes restrictions, resulting in reduced segmentation of demand

Fare Simplification Reduces Segmentation

Fare Code	Dollar Price	Advance Purchase	Round Trip?	Sat. Night Min. Stay	Percent Non-Refundable
Y	$500	--	--	--	--
B	$375	7 day	--	--	50 %
M	$250	14 day	--	--	100 %
Q	$190	21 day	--	--	100 %

- With fewer restrictions on lower fares, some Y (business) passengers are able to buy B, M and Q.
- Keeping B, M, Q classes open results in “spiral down” of high fare passengers and total revenues.

BOS-SEA Fare Structure

American Airlines, October 1, 2001

Roundtrip Fare ($)	Cls	Advance Purchase	Minimum Stay	Change Fee?	Comment
458	N	21 days	Sat. Night	Yes	Tue/Wed/Sat
707	M	21 days	Sat. Night	Yes	Tue/Wed
760	M	21 days	Sat. Night	Yes	Thu-Mon
927	H	14 days	Sat. Night	Yes	Tue/Wed
1001	H	14 days	Sat. Night	Yes	Thu-Mon
2083	B	3 days	none	No	2 X OW Fare
2262	Y	none	none	No	2 X OW Fare
2783	F	none	none	No	First Class

BOS-SEA Simplified Fare Structure

Alaska Airlines, May 1, 2004

Roundtrip Fare ($)	Cls	Advance Purchase	Minimum Stay	Change Fee?	Comment
374	V	21 days	1 day	Yes	Non-refundable
456	L	14 days	1 day	Yes	Non-refundable
559	Q	14 days	1 day	Yes	Non-refundable
683	H	7 days	1 day	Yes	Non-refundable
827	B	3 days	none	No	2 X OW Fare
929	Y	none	none	No	2 X OW Fare
1135	F	none	none	No	First Class

In Retrospect, the Airline RM Problem was Relatively Simple

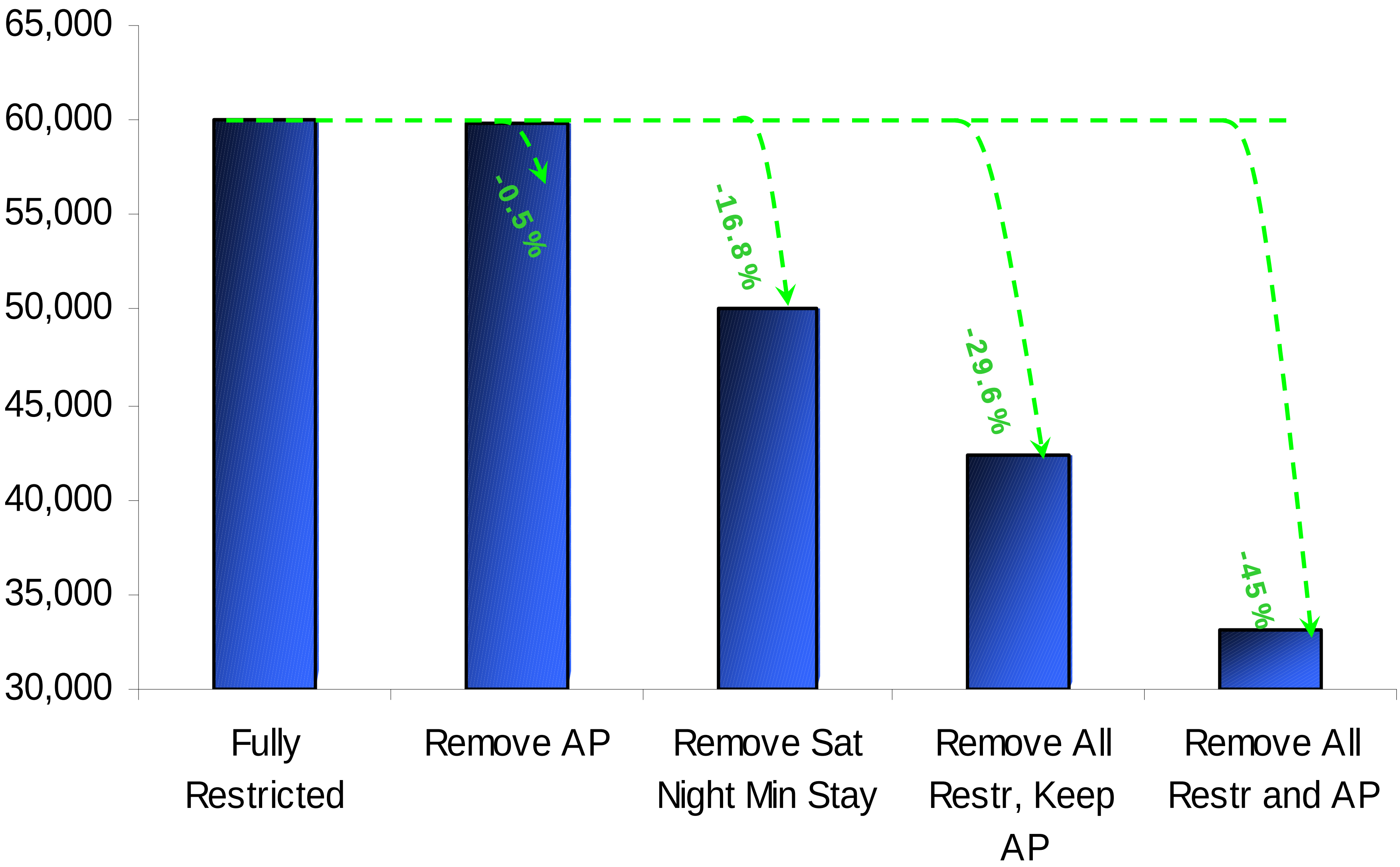
- **Fundamental assumptions of traditional RM models:**
  - Multiple fare levels offered on same flight, same itinerary
  - Each has different restrictions and characteristics
  - Demand for each fare class is independent and identifiable
  - Passengers will only buy their preferred fare product
- **Implications for forecasting:**
  - Future demand can be predicted based on historical bookings in each fare class
  - Time series statistical methods used by most RM systems
- **Implications for optimization:**
  - Given independent demand forecasts and remaining capacity, optimize booking limits for each fare class by flight or network

"Spiral-Down" in Traditional RM Systems

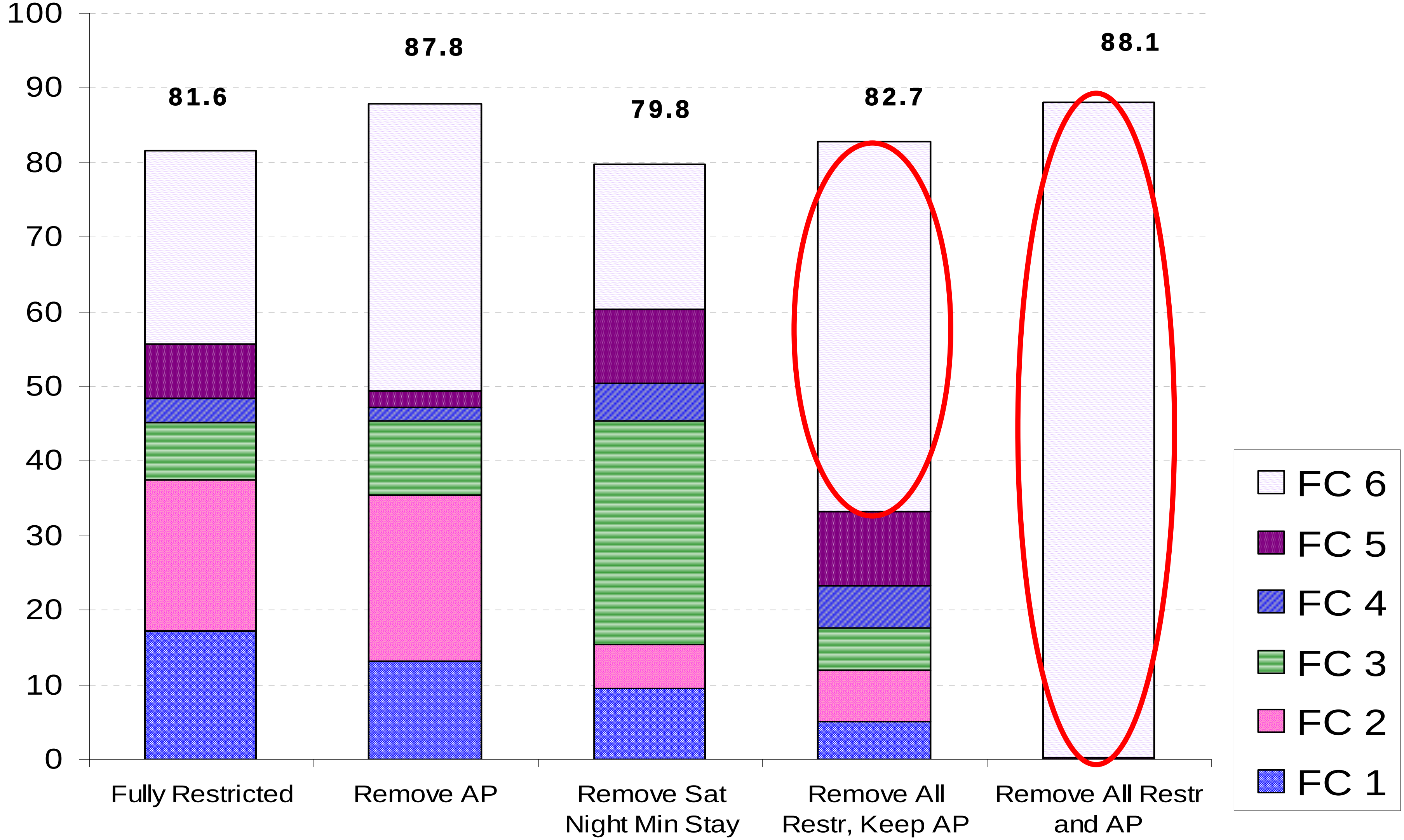
- **Simplified fare structures characterized by**
  - One-way fares with little or no product differentiation, priced at different fare levels
  - Without segmentation, passengers buy the lowest available fare

- **Fare class forecasts based on historical bookings will under-estimate demand for higher fare levels**
  - Previous "buy-down" is recorded as lower fare demand
  - EMSRb under-protects based on under-forecasts of high-fare demands
  - Allowing more buy-down to occur, and the cycle continues

Revenue Impacts of Fare Simplification with Traditional RM Models



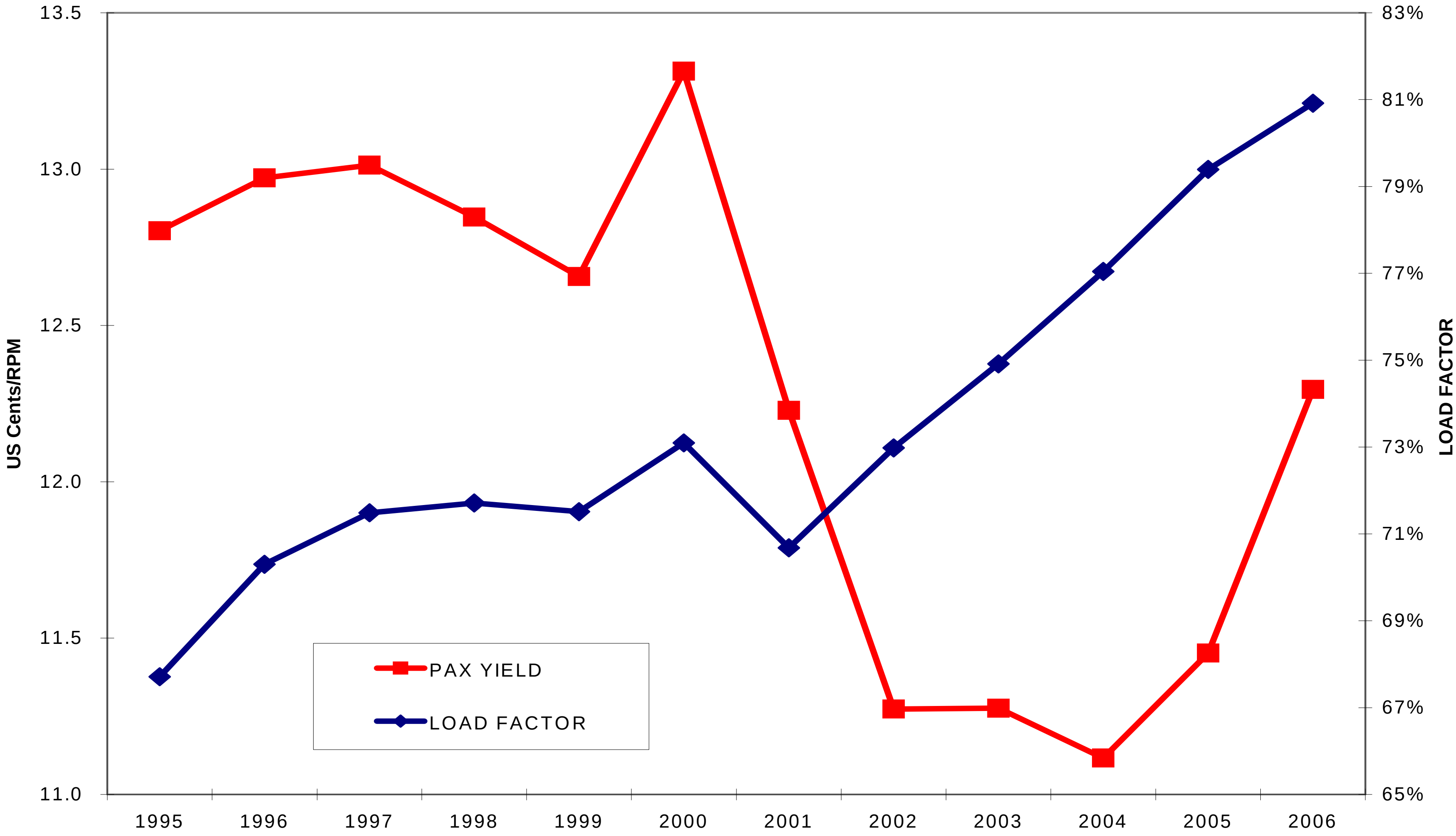
Traditional RM Models "Spiral Down" without Product Differentiation



Airline RM Systems Are Struggling Under Fare Simplification

- **Primary responsibility for revenue maximization has shifted from pricing to RM**
  - Simplified fares still offer just as many price levels, but segmentation restrictions have been removed
  - Existing RM systems still employed to control number of seats sold at each fare level
- **Current RM system limitations are negatively affecting airline revenues**
  - Existing systems, left unadjusted, generate higher load factors but lower yields
  - Many legacy carriers are using “rule-based” RM practices, for lack of a systematic approach to revenue maximization

US Network Carrier Yields and Load Factors 1995-2006



Can Existing RM Systems be Saved?

- **For traditional RM systems, what tools can reclaim revenues lost to simplified fares?**
  - Focus on models tested in PODS simulation research at MIT

- **Is development of Network RM (O+D control) still worthwhile?**
  - Comparison of Network RM revenue gains to Leg-based RM enhancements

- **How much of the revenue lost to simplification can be recouped with these models?**

Current RM Challenge: Changing and Different Fare Structures

1. **Fully Undifferentiated Fare Structures**
   - Multiple fare levels with no differentiation of fare products, with only one fare level available at a given point in time
2. **Semi-Restricted ("Simplified") Fare Structures**
   - Combination of differentiated fare products and loosely restricted undifferentiated fares in same market
3. **Mixed Networks with Multiple Fare Structures**
   - How to control seat availability in unrestricted fare LCC markets while managing seats in more traditional fare markets
   - Seats on a flight leg shared by passengers in both types of markets

New Developments in RM Modeling

- **Forecasting and optimization methods to reverse and prevent spiral down in different fare structures**
  - Incorporate willingness to pay (WTP) or “sell-up” probabilities
- **Several new approaches show promising results**
  - “Q-forecasting” by WTP (Hopperstad and Belobaba)
  - Hybrid Forecasting (Boyd and Kallesen)
  - Fare Adjustment in Optimization (Fiig and Isler)
- **Methods developed and/or tested in MIT PODS research consortium**
  - Funded by seven large international airlines
  - Passenger Origin Destination Simulator used to evaluate revenue impacts of RM models in competition markets

Q-Forecasting of Price-Oriented Demand

- **Q forecasting assumes fully undifferentiated fares**

Conversion of historical bookings to equivalent Q-bookings

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Detruncation is applied to equivalent Q-bookings

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Forecast of Q-bookings to come

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Forecast of potential demand to come by fare class

Scale historical bookings by **1 / (sell-up rate)**

Apply **sell-up rates** to generate forecasts for higher fare classes

Hybrid Forecasting For Simplified Fare Structures

- ***Hybrid Forecasting*** **generates separate forecasts for price and product oriented demand:**

- Price-Oriented:
  - **Passengers will only purchase lowest available class**
  - **Generate conditional forecasts for each class, given lower class closed**
  - **Use “Q-Forecasting” by WTP**

- Product-Oriented:
  - **Passengers will book in their desired class, based on product characteristics**
  - **Use Traditional RM Forecasting by fare class**

Forecast of total demand for itinerary/class

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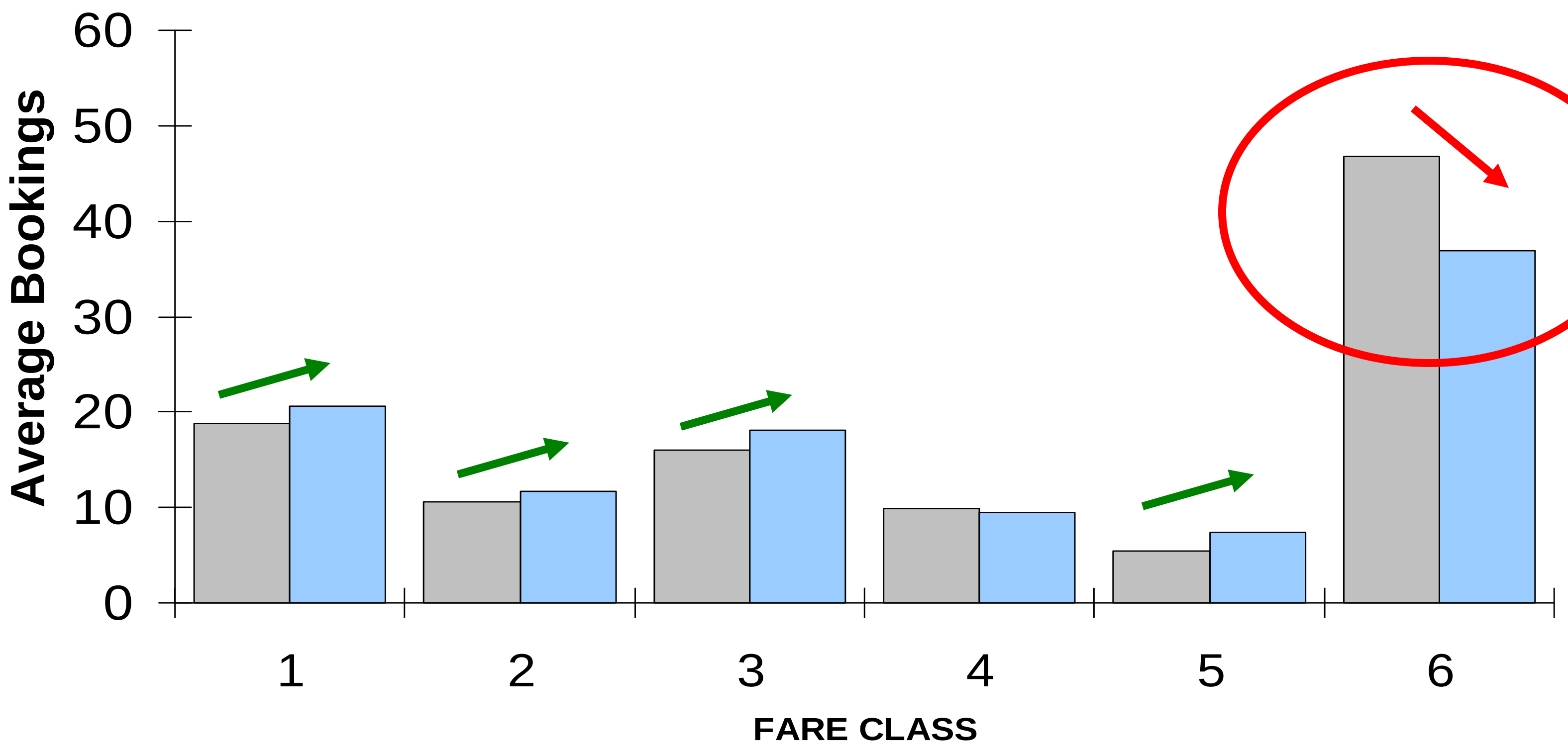
Change in Fare Class Mix – EMSRb+HF

- **Load Factor drops from 86.7% to 83.7%, but yield increases as fewer bookings are taken the lowest fare class.**



Fare Adjustment Methods

- **Modify fare inputs to optimizer to prevent buy-down**
  - Incorporates sell-up into optimization logic when higher-class bookings depend entirely on closing down lower classes
  - Developed by Fiig (SAS) and Isler (Swiss)
  - Mathematically similar to previous EMSR “sell-up” models (Belobaba and Weatherford)

- **Fare Adjustment in existing leg/class RM systems**
  - Average fare for each bucket is the weighted average of adjusted fares for path/classes in bucket
  - Fare adjustment reduces availability to lowest fare classes in LCC markets

Leg-Based Fare Adjustment Principle

Instead of feeding the EMSR optimizer with fare values optimize with:

O-D Fare – **Price Elasticity Cost**

Net Fare

Reduction due to risk of buy-down

Decreases the adjusted fares of LCC markets

Changes the fare ratios in EMSR optimizer

Increases seat protection for higher fare classes with sell-up potential

Reduces availability to lowest fare classes and encourages sell-up

Different ways to compute the Price Elasticity Cost:

- Thomas Fiig's MR (continuous)
- Karl Isler's KI (discrete)

EMSRb Controls with Fare Adjustment

NO FARE ADJUSTMENT

FC	Average Fares	Mean Demand	Std Dev	Booking Limits
1	$350.00	15	5	100
2	$225.00	13	8	87
3	$190.00	16	7	76
4	$160.00	20	9	60
5	$110.00	30	11	36
6	$90.00	38	6	5

WITH FARE ADJUSTMENT

FC	Adjusted Fares	Mean Demand	Std Dev	Booking Limits
1	$ 350.00	15	5	100
2	$ 193.49	13	8	84
3	$ 128.20	16	7	71
4	$ 96.13	20	9	54
5	$ 54.42	30	11	28
6	$ 21.66	38	6	-13

- Fare Adjustment takes into account the probability of sell-up, and the “price elasticity” opportunity cost.
- Fewer seats allocated to the lower fare classes; lowest class 6 is closed down.

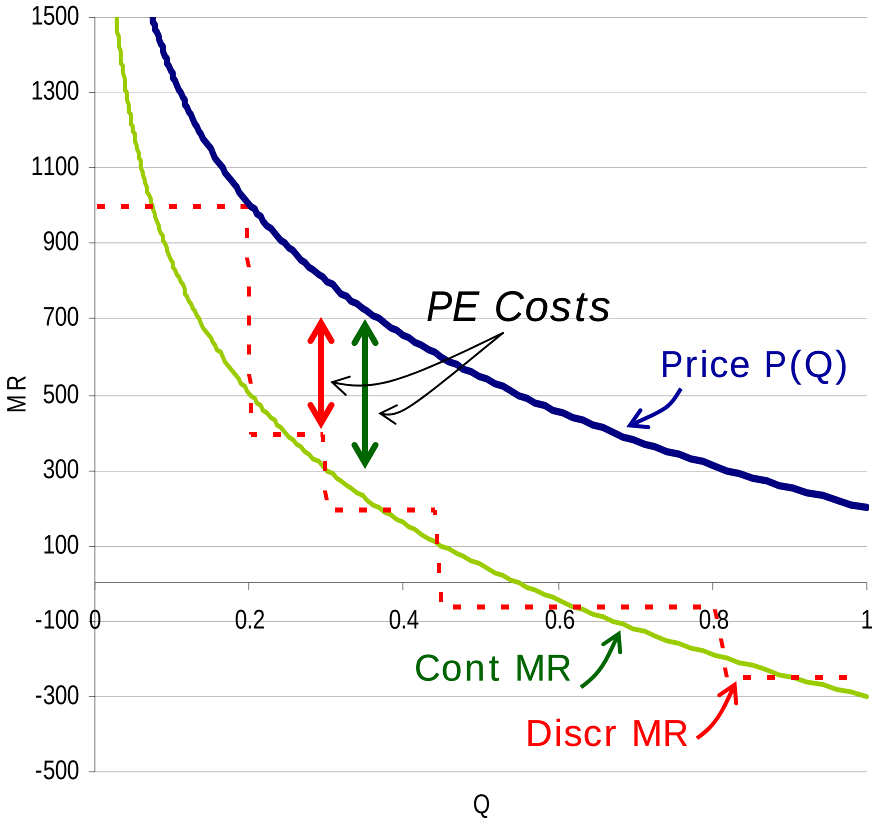
Network RM with Hybrid Forecasting and Fare Adjustment

- **Greatest revenue gains of existing RM methods for less restricted fare structures come from:**
  - O-D Control: Path-based forecasting and network optimization, with availability controlled by virtual buckets (DAVN) or bid prices (ProBP)
  - Hybrid Forecasting: Separate forecasting of price- vs. product-oriented demand in all markets (LCC and traditional) requires explicit WTP forecasts for price-oriented demand
  - Fare Adjustment Optimization Logic: Price-oriented demands subject to fare adjustment which maps availability to lower buckets and/or below bid price.
- **These 3 components combine to provide Airline 1 with 3.86% revenue gain over standard Leg RM.**

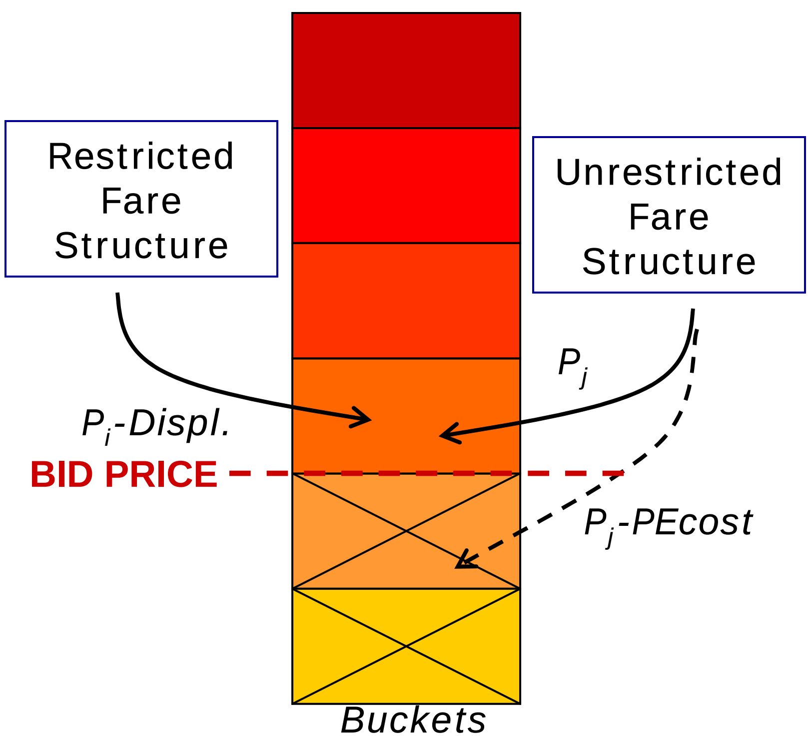
O-D Control Fare Adjustment

The Price Elasticity is **estimated**.

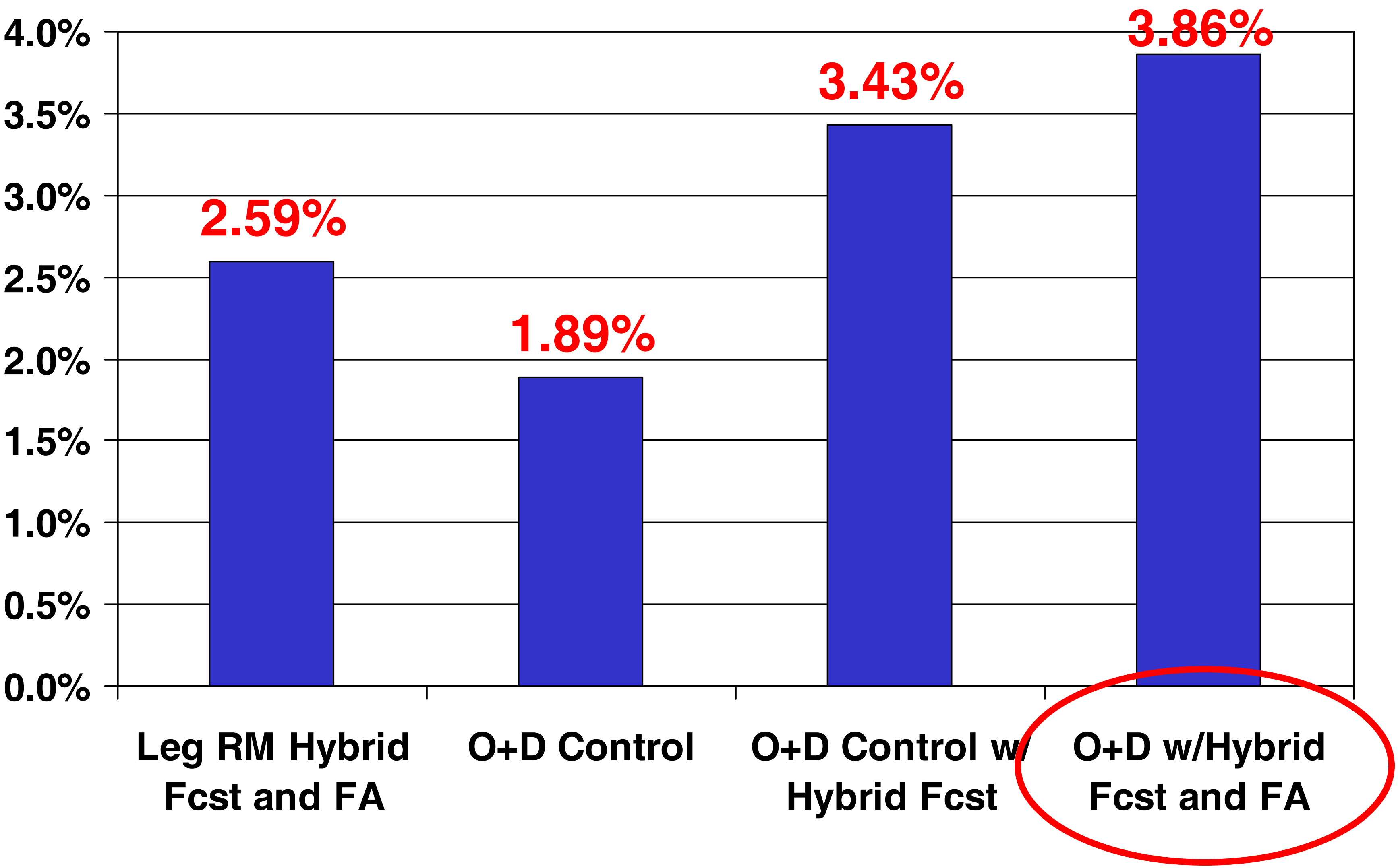
$$\boxed{PEcost = ODFare\ P - MR}$$



Leg
Buckets



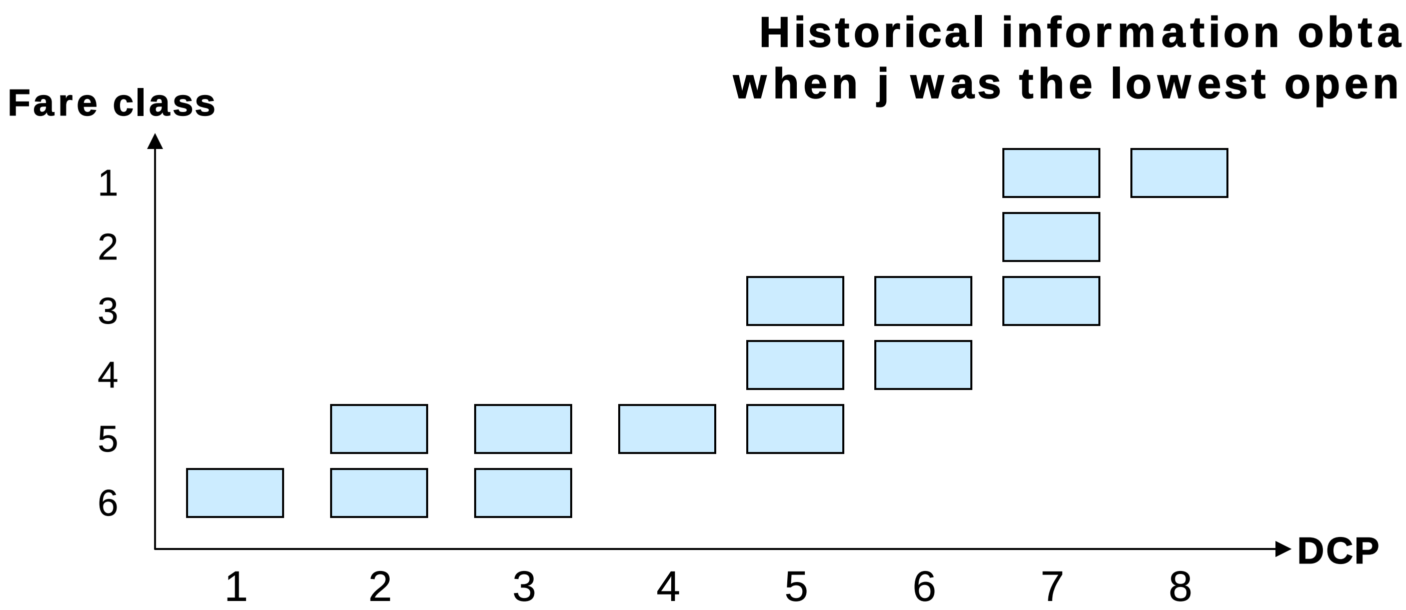
Hybrid Forecasting and Fare Adjustment



Existing RM Systems Are Inadequate for Changing Fare Structures

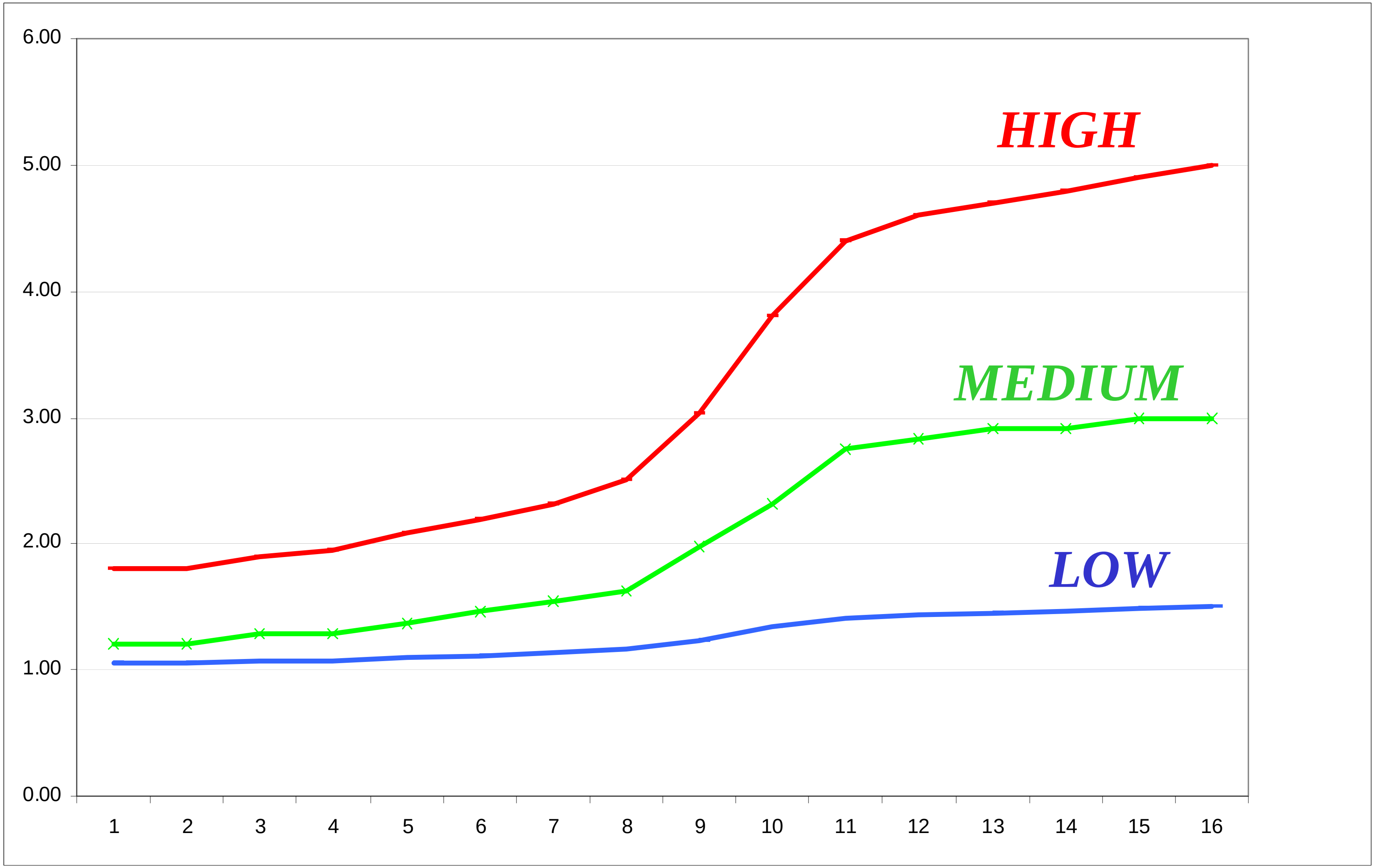
- **Forecasters and optimizers need to be modified**
  - Mismatch between RM model assumptions and fare structures
- **Price/product hybrid forecasting of demand**
  - Gains come from higher forecasts in upper/middle classes, increasing protection and helping to reduce “spiral down”
- **Fare adjustment in optimization models**
  - Passenger values adjusted to reflect risk of buy-down and willingness to pay (WTP)
- **But, both new methods require estimates of passenger WTP by time to departure for each flight**

Sell-up Rates Must Be Estimated from Historical Observations



- **On a single flight departure, bookings in each class observed only when lower class was closed down.**
- **With information about class closures and observed bookings, need to estimate WTP and sell-up rates**

Willingness to Pay Relative to Lowest Fare Changes over the Booking Process



BOOKING PERIODS (DCPs)

Bringing OR Back to Airline RM

- **OR contributed to the great success in airline RM:**
  - Good acceptance of RM models by management and users alike enabled a shift away from judgmental approaches
- **Recently, RM systems have suffered setbacks:**
  - Return to “rule-based” decision-making due to lack of faith in existing (and inappropriate) RM forecasters and optimizers
  - Self-perpetuating – users become more comfortable with rules, less willing to test new scientific solutions
- **Challenge is to bring science back to RM:**
  - Development, testing and acceptance of new models for forecasting, optimization and estimation of willingness to pay

Can Existing RM Systems Be Saved?

- **Our research results suggest the answer is "YES"**
  - Available RM enhancements described here can increase revenues by 3-4% over traditional leg-based RM systems
  - O+D Control with Hybrid Forecasting and Fare Adjustment combine to successfully reverse and prevent dilution

- **Yet, many airlines have not implemented RM model enhancements to respond to fare simplification**
  - Doing almost anything to reverse spiral down is better than doing nothing, and more systematic than user overrides
  - Biggest research/development challenge is estimation of willingness to pay and consumer choice models