

Demand forecasting in revenue management

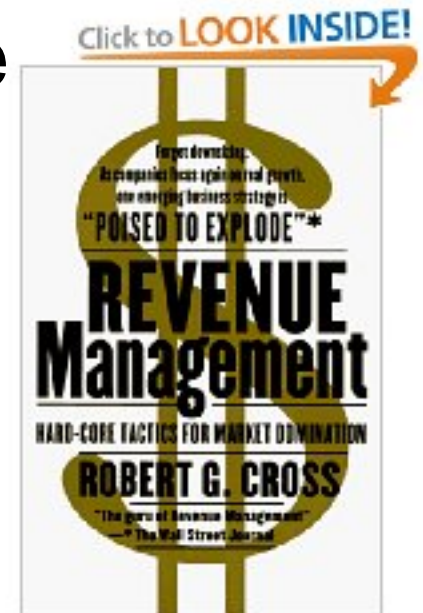
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Universiteit Antwerpen, 8 May 2009



Cost vs revenue

- Standard management practice: cut costs to improve profitability
- Revenue management: influence price to change demand as to match supply and maximize revenue



Pricing

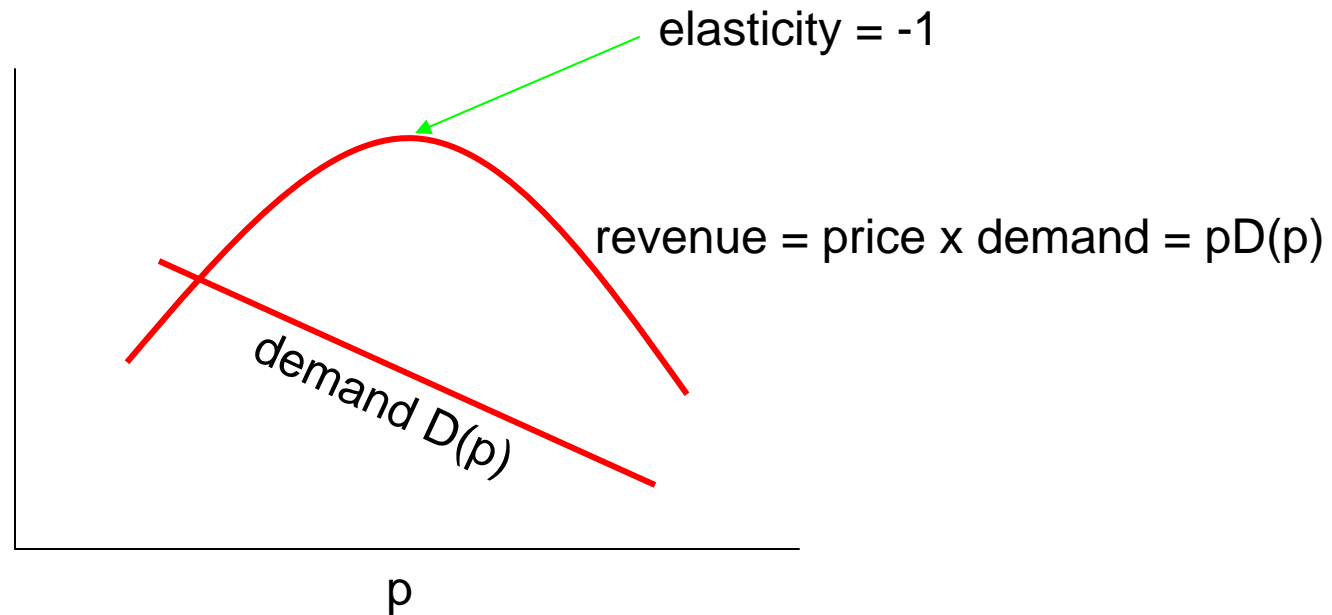
- price p , demand $D(p)$
- revenue = $pD(p)$
- price elasticity = $E(p) = pD'(p)/D(p)$, rel diff in demand under rel changes in demand
- $E(p) < 0$
- revenue maximal if $E(p) = -1$

$$\Leftrightarrow \frac{d}{dp} pD(p) = 0$$



Demand curve

- Maximizing revenue $\Leftrightarrow d/dp \ pD(p) = 0$

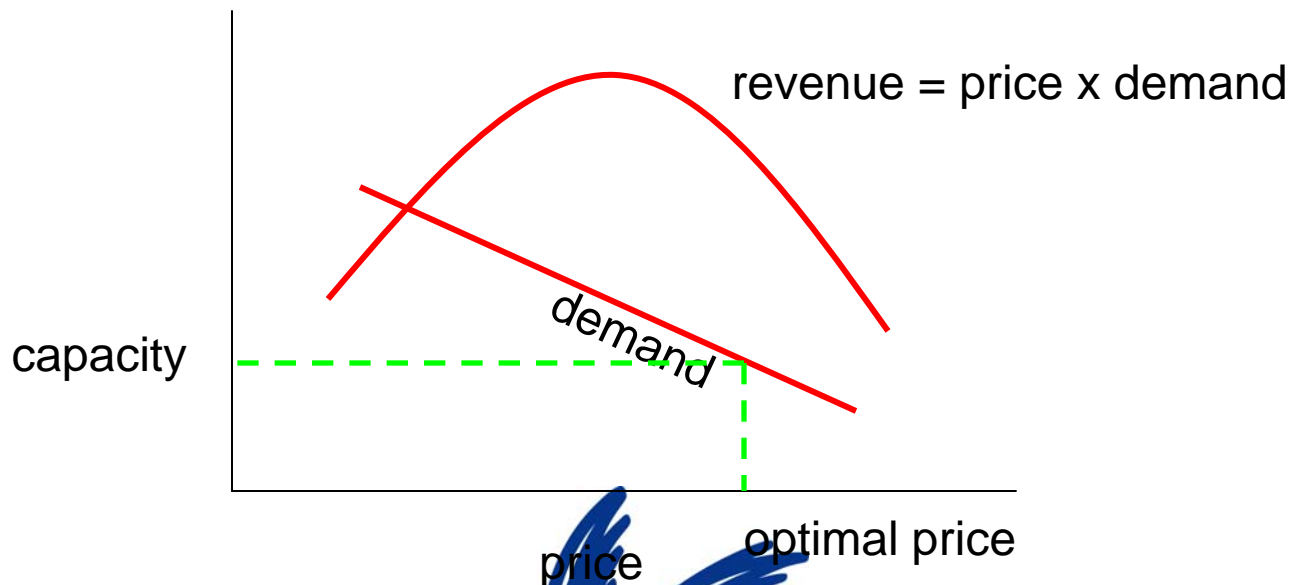


- difficulty: obtaining form demand curve D(p)



Insufficient capacity

- What if capacity fixed & insufficient?
- Take price as to meet capacity exactly
- But: demand is random



Market segmentation

- “Micromarkets”
 - business/leisure
 - different sales channels
- Assigning capacity to different market segments/
customer classes: **revenue management**

Kies uw vertrek- en retourdatum.

Hulp nodig?

Vertrek
maandag 11 mei 2009
Van Amsterdam naar New York

mei

Ma	Di	Wo	Do	Vr	Za	Zo
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18						

later >>

Retour
maandag 18 mei 2009
Van New York naar Amsterdam

mei

Ma	Di	Wo	Do	Vr	Za	Zo
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25						

<< eerder later >>

Kies tarief

Economy

RETOUR tarieven per
persoon incl. belasting en
toeslagen (excl.
reserveringskosten)

De wereld dichterbij

401

Instapprijzen

487

618

Selecteer

Instapprijzen (flexibel)

681

777

Selecteer

Ticketprijs inclusief
belasting(en) en toeslagen

EUR 399

Revenue management

Conditions:

- Fixed capacity
- Service (no delayed consumption)
- Customer segmentation

Often:

- Low variable costs
- Random demand
- High-paying customers “arrive” late



“Success” story



vs.



- People Express was low-cost carrier
- AA introduced supersaver tariff
- lower than PE tariffs, only when capacity available
- CEO: reason bankruptcy PE (1987)
- Essentiel: good forecast (+ ...)



Another success story (Interfaces 97)

Revenue Management Saves National Car Rental

In 1993, National Car Rental faced liquidation. General Motors Corporation (National's parent) took a \$744 million charge against earnings related to its ownership of National Car Rental Systems. National faced liquidation, with the loss of 7,500 jobs, unless it could show a profit in the short term. National initiated a comprehensive revenue management program whose core is a suite of analytic models developed to manage capacity, pricing, and reservation. As it improved management of these functions, National dramatically increased its revenue. The initial implementation in July 1993 produced immediate results and returned National Car Rental to profitability. In July 1994, National implemented a state-of-the-art revenue management system, improving revenues by \$56 million in the first year. In April 1995, General Motors sold National Car Rental Systems for an estimated \$1.2 billion.

Industries

- Airlines
- Car rental
- Hospitality
- Cinema
- Advertising (on tv and online)
- Parking
- ...



Crucial steps in RM

- Characterizing customer behavior
 - Forecast
 - Diversion to other products/times
- Optimization module
 - determines prices/booking limits



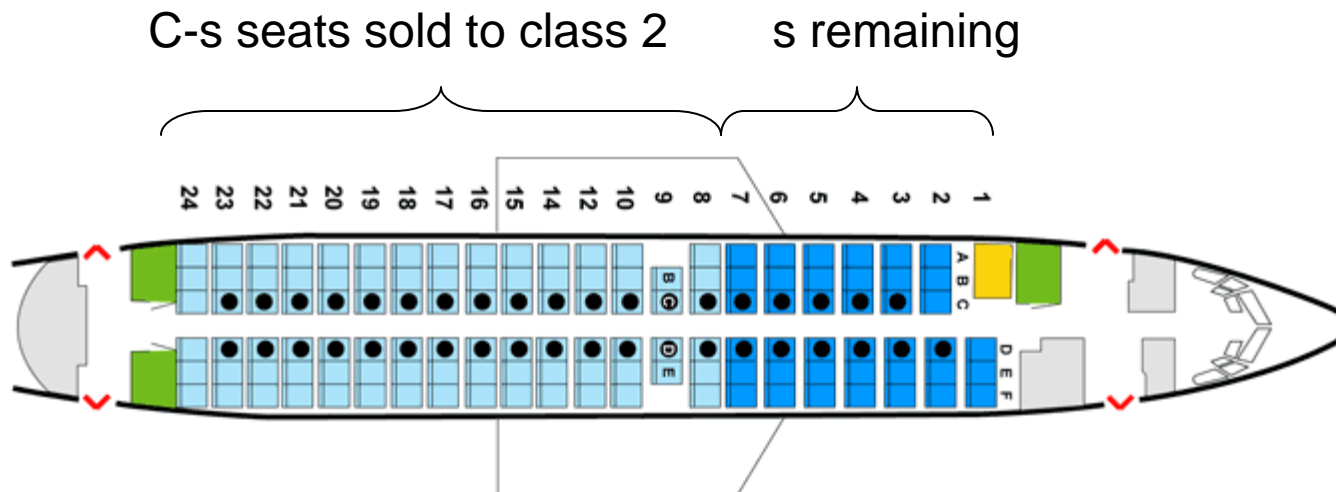
Littlewood's model

- Simplest stochastic RM model
- 2 classes
- Parameters
 - demand D_1, D_2
 - revenue $y_1, y_2, y_1 > y_2$
 - capacity C
 - class 1 books after class 2
- How much capacity to reserve for class 1?



Littlewood's model

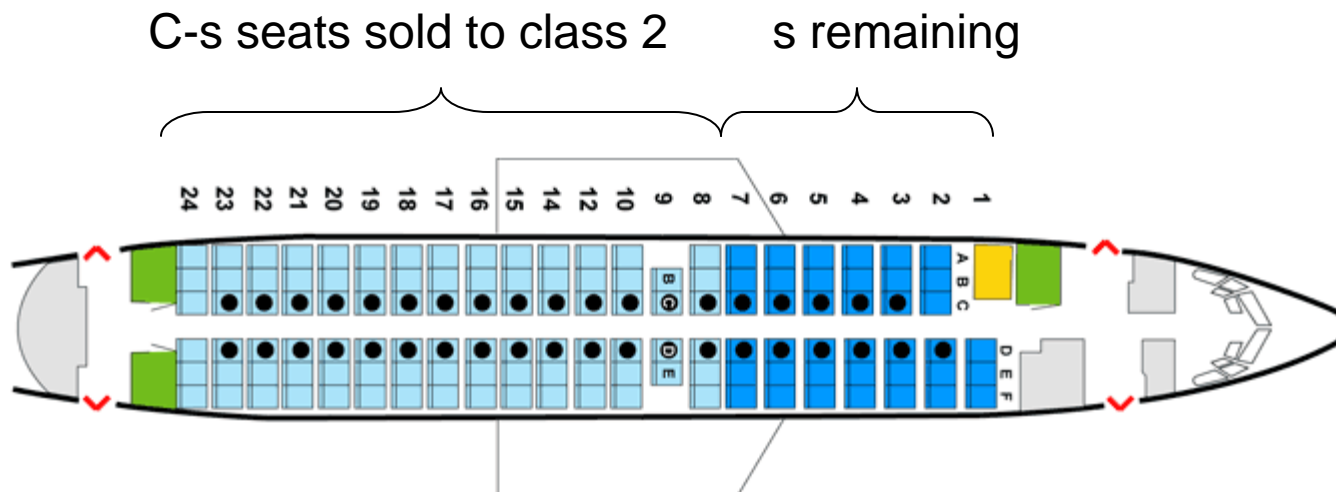
- Sell “seats” one by one to class 2
- When is it optimal to stop?
- Suppose s seats remaining



Littlewood's model

- Is it optimal to sell the s th seat to class 2?
- Revenue selling it to class 2: y_2
- Expected revenue selling it to class 1:

$$y_1 P(D_1 \geq s)$$



Littlewood's model

- Optimal booking limit s^* : $y_2 \approx y_1 P(D_1 \geq s^*)$
- $P(D_1 \geq s) = 1 - F(s)$
- $F(s^*) = (y_1 - y_2) / y_1 \Rightarrow s^* = F^{-1}((y_1 - y_2) / y_1)$
- special case of newsvendor problem

- Example: $y_1 = 500$, $y_2 = 200$, $D_1 \sim \text{Poisson}(10)$
- $P(D_1 \geq 12) = 0.3$, $P(D_1 \geq 11) = 0.42$, $P(D_1 \geq 10) = 0.54$
- Reserve 11 seats for class 1



Disadvantages Littlewood

- Reality: booking period overlap
- Class-1 customers show *buy-down* effect if class 2 still open
- Result:
 - Less revenue from class 1
 - Class-1 demand partially observed as type-2 bookings



Improving Littlewood

- Two issues:
 - optimal policy
 - demand estimation(taking into account the constrained nature of the observations)



Booking policy

- The optimal policy:
 - depends on current demand, remaining demand, remaining capacity
 - closes (and opens) class 1
 - computed by dp
 - or: rules of thumb
- Other aspects: multiple classes, multiple legs, diversion to other flights, overbooking, overselling,...



Demand forecasting

- Problem: Some class-1 demand is observed as type-2 sales
- Can be misinterpreted as class-2 demand
- Leads to an underestimation of class-1 demand
- Sales go up, revenue goes down
- *Spiral-down effect*

Cooper, Homem-de-Mello, Kleywegt, OR 2006



Demand forecasting

- *Unconstraining* essential
- Model for customer buy-down behavior: *customer choice sets*
- CCS: a number of booking classes
 - a customer chooses from its CCS the lowest open class
- Examples: {2} (leisure: only class 2), {1,2} (willing to pay high price, chooses lowest)



Demand forecasting

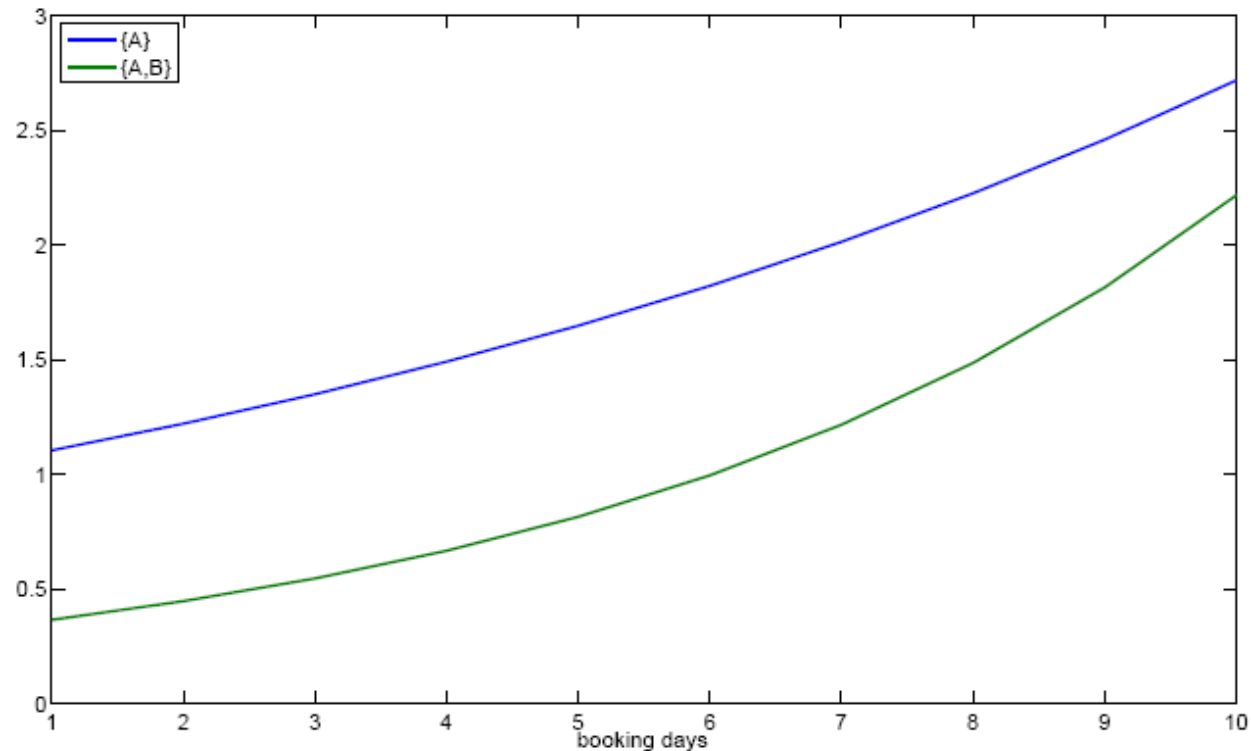
- Research project with KLM data
- joint work with Alwin Haensel (MSc Berlin)
- start with lab environment
- demand follows inhomogeneous Poisson process with rate (inspired by the data):

$$\lambda_s(t) = \beta_s \exp(\alpha_s t)$$



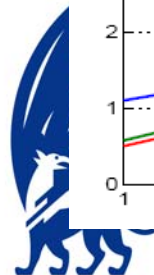
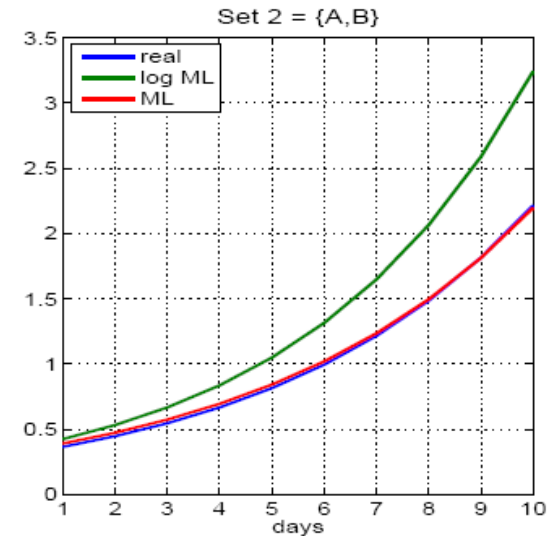
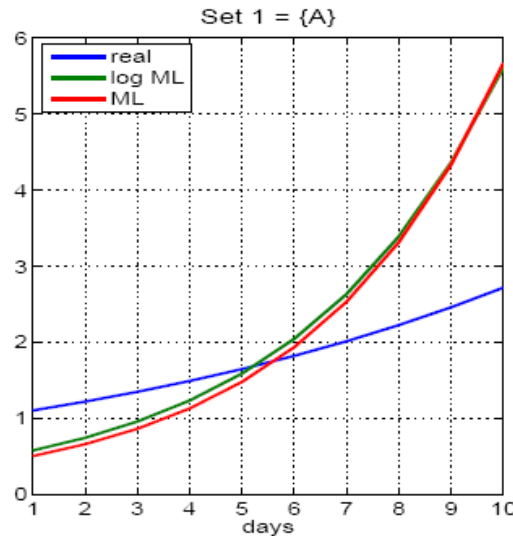
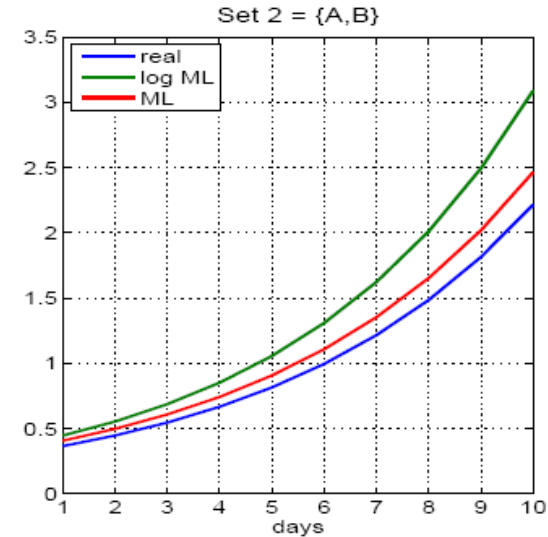
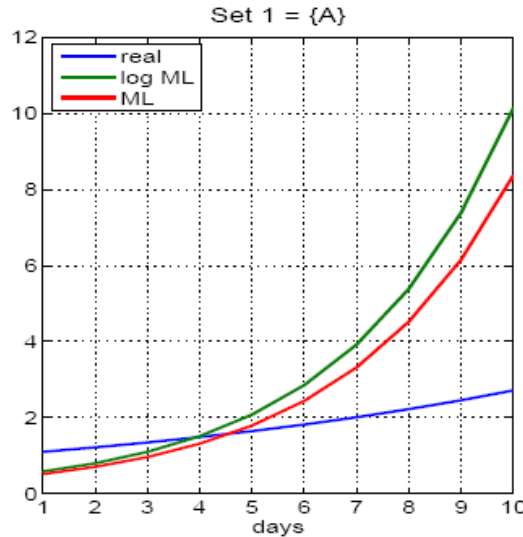
Demand rate

	α	β	Mean Demand	Price
{A}	0.1	1	16.1	50
{A, B}	0.2	0.3	9.3	200



Experiment

- Simulate with given booking policy
- Estimate using MLE (including buy-down behavior)
- Results (for different booking policies):



Next steps

- Compute optimal policy and rules of thumb
- Compute revenue for rules based on estimated demand function
- Compute revenue loss
- Validate with real data

Ongoing work

