Quantitative Decision Making in Business

Summer University 2018

Topic 10: Revenue Management

Technische Universität Berlin

Lecturer:
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Agenda

Airline Revenue Management

- Actual Situation in the Airline Industry
- Revenue Management Optimization Problem
- Model Assumptions
- Capacity-Based Booking Control
  - Static Model
  - Dynamic Model

Actual Situation in the Airline Industry

Practice of Airline RM
is known as a synergy of

aggressive pricing
and a

tactical inventory control
under demand uncertainty and permanently changing marketconditions.

- 1978: Airline Deregulation Act in the U.S.
  - Returned full power of decision making back to the companies
  - Opened the market for new competitors
- Low-cost carriers exploited the market of financially less strong customer groups
  - Fares up to 70% lower than the established carriers
  - Very low operating costs
  - Example: LCC PeopleExpress (1981) generated in the following two years a revenue of $1 billion, and in their third year a profit of $60 million
- 1985: American Airlines introduced Ultimate Super Saver Tickets
  - Idea: selling seats at marginal costs
  - Generates additional revenue for marginal costs almost zero
- 1987: PeopleExpress‘s bankruptcy (like a lot of other LCC)

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Actual Situation in the Airline Industry

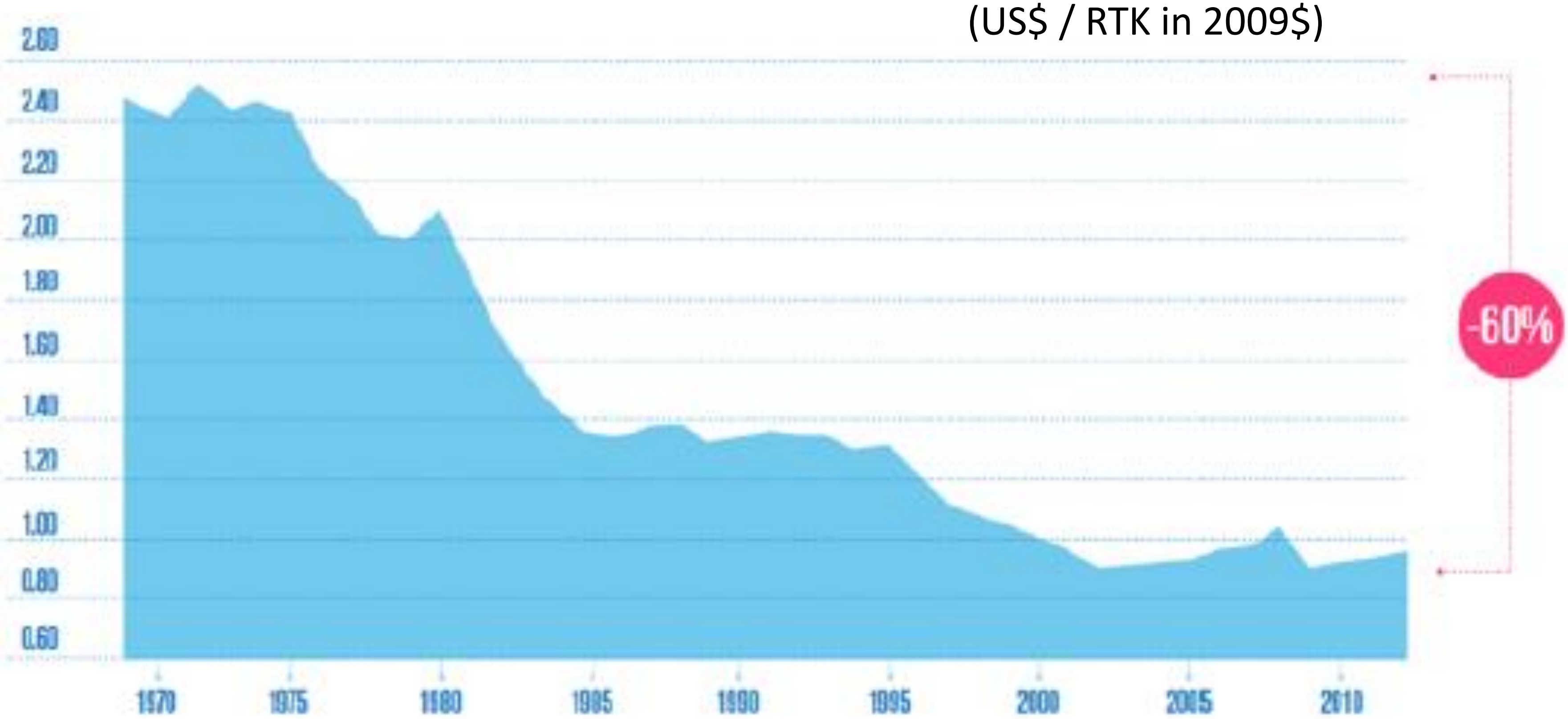
"The quickest way to become a millionaire in the airline business is to start out as a billionaire."

- Richard Branson 2001 –

- In many industrial sectors the focus for generating more profit lays on **reducing cost** or extending the product offerings.

Actual Situation in the Airline Industry

The real price of air transport
(US$ / RTK in 2009$)



Source : Brian Pearce. Profitability and the Air Transport Value Chain. *IATA Economics Briefing*, No. 10, 2013.

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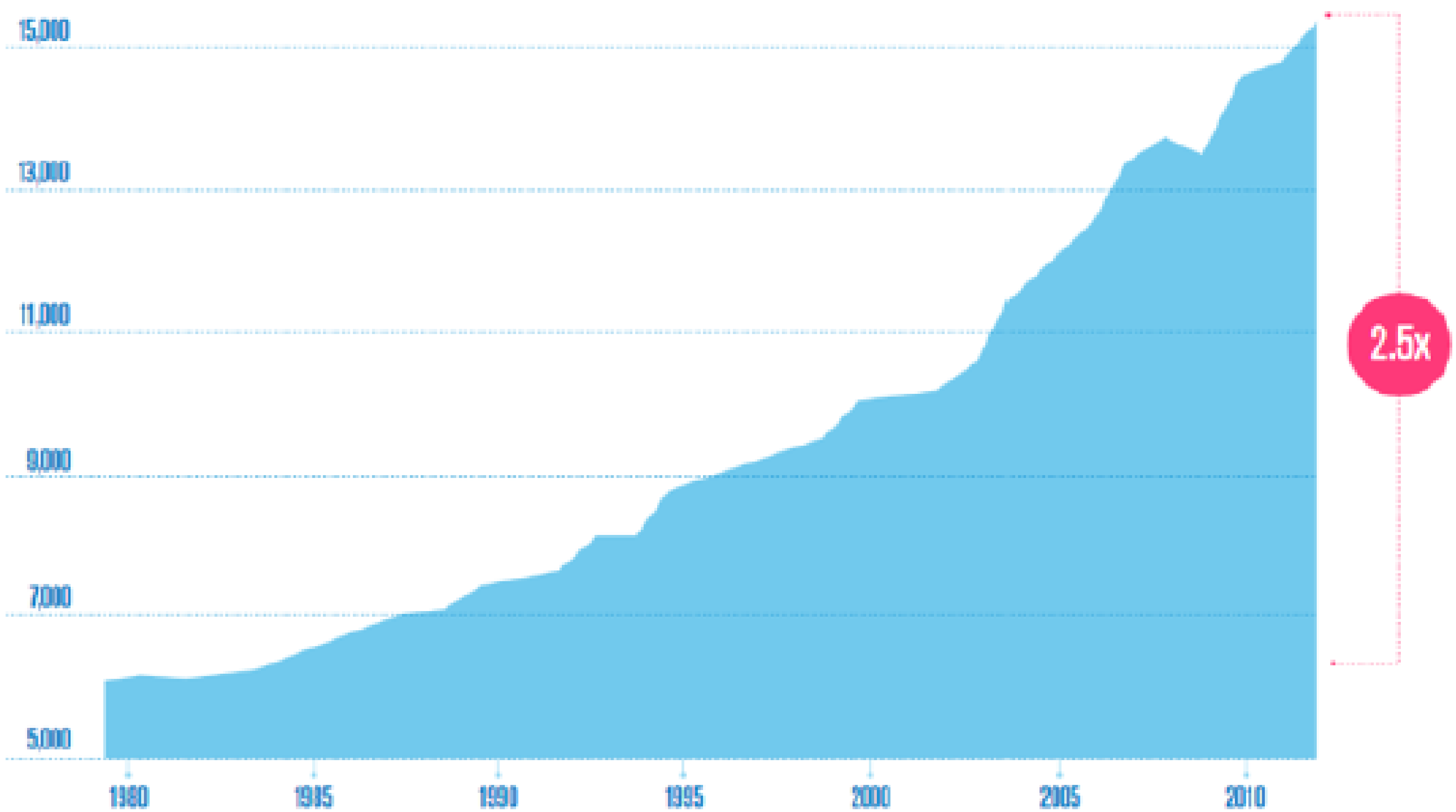
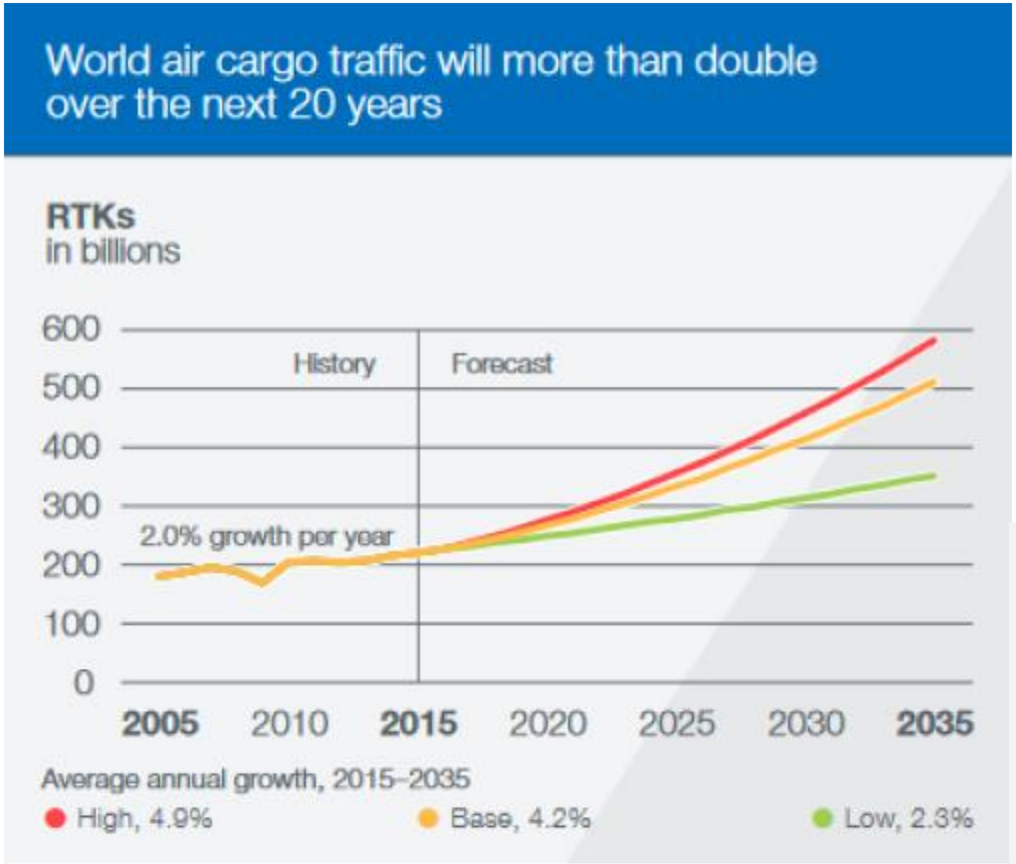
The number of direct city pair air services

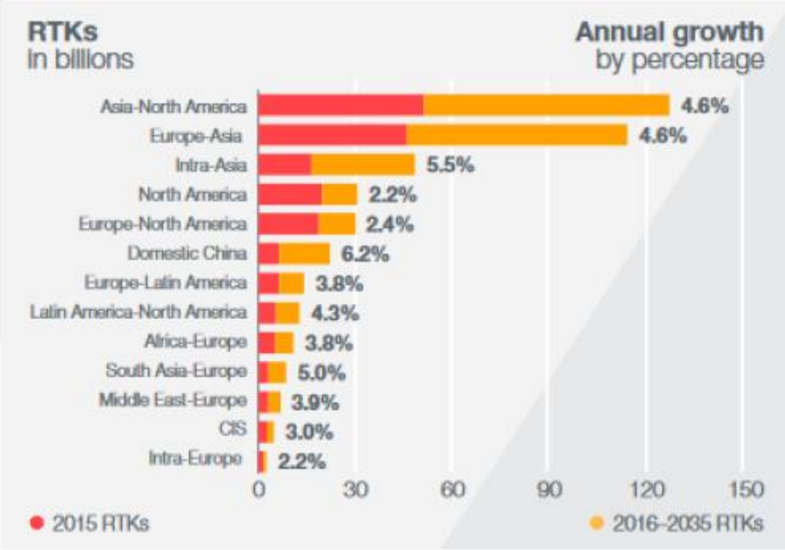


History of world air cargo traffic and prognosticated trend



Source : Boeing Commercial Airplanes. World air cargo forecast 2016 - 2017. *annual report*, 2016.

World distribution of air cargo traffic flows and growth rates



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Actual Situation in the Airline Industry

"The quickest way to become a millionaire in the airline business is to start out as a billionaire."

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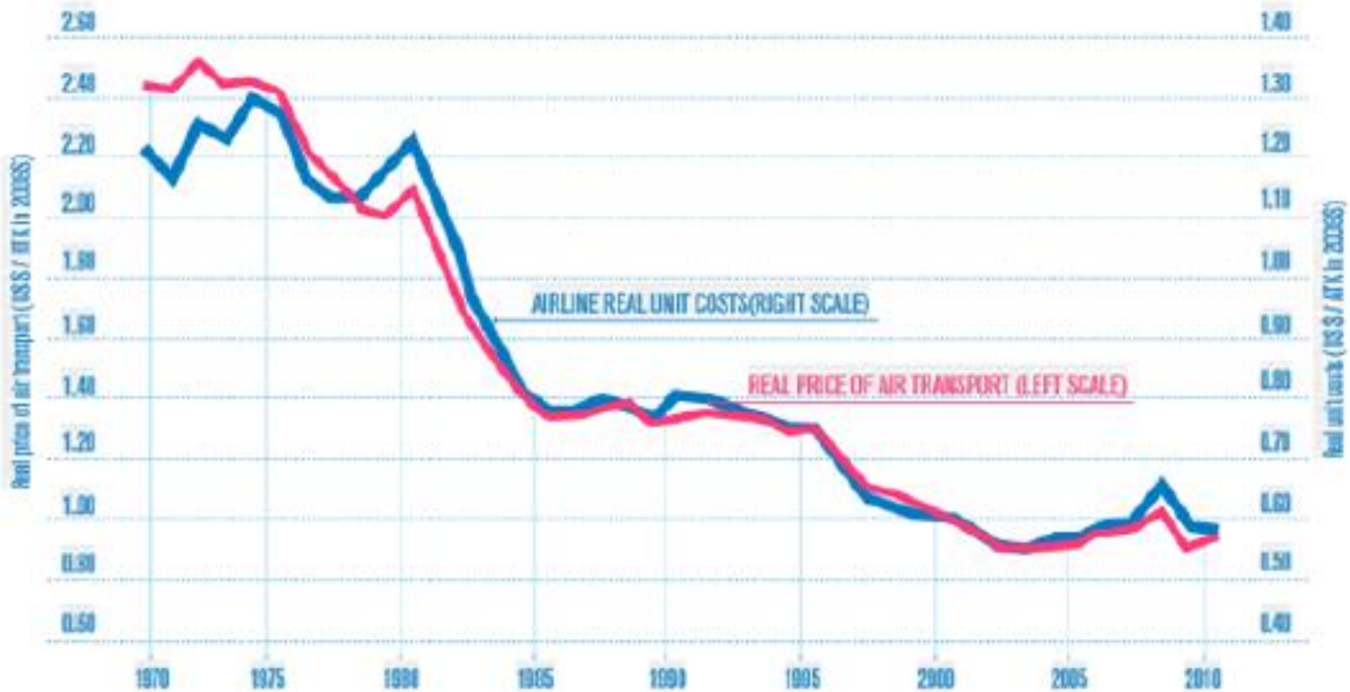
- In many industrial sectors the focus for generating more profit lays on reducing cost or extending the product offerings.
- **Question:** Why are airlines widley believed to be a money-lossing business?

Development of airport charges between 2006 and 2016

Source : http://www.iata.org/pressroom/pr/Documents/airport-charges-infographic.png

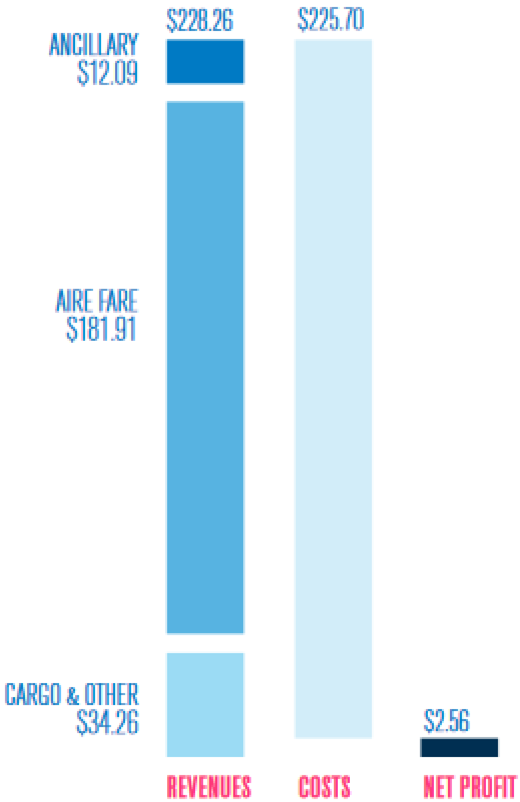
The real price of air transport and real unit costs



Source : Brian Pearce. Profitability and the Air Transport Value Chain. *IATA Economics Briefing*, No. 10, 2013.

- Since passing of the ADA the airline industry has reduced the costs by 50% in real terms (blue line)
- This transformed air traveling into an elementary service which is accessible to the general public

Why are airlines widley believed to be a money-lossing business?



2012 worldwide airline financial results per departing passenger

Source : Brian Pearce. Profitability and the Air Transport Value Chain. *IATA Economics Briefing*, No. 10, 2013.

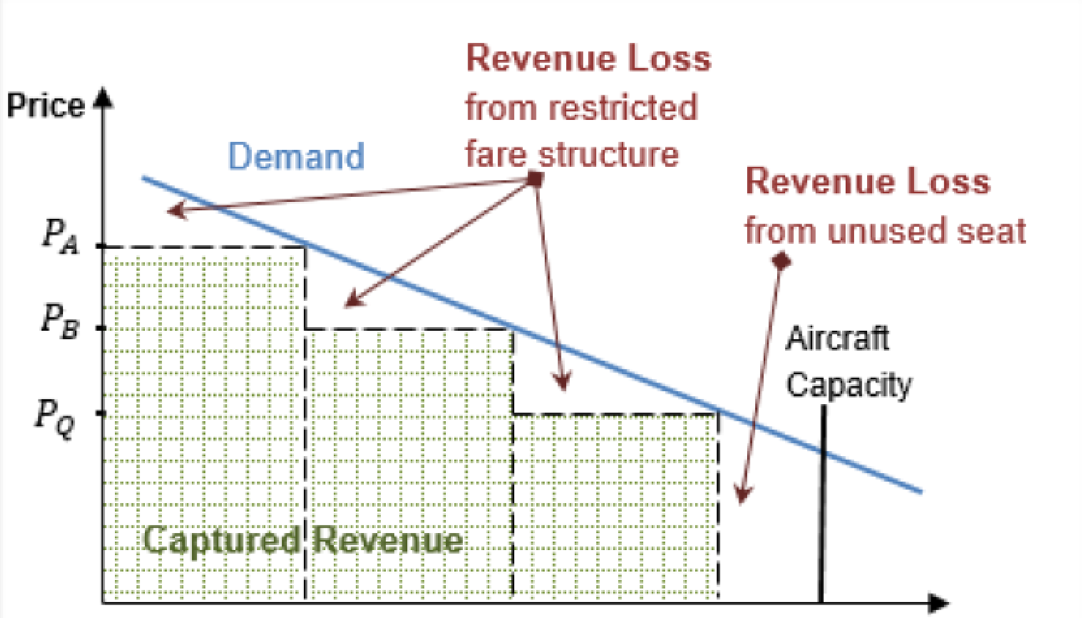
"The worst sort of business is one that grows rapidly, requires significant capital to engender the growth, and then earns little or no money. Think airlines."

- Warren Buffett 2007 –

- Very small return on invested capital (less than 7%)
  - Compare: Pharmaceuticals at 25%
    IT Services at 20%
    Restaurants at around 15%
- Cost reductions were passed through to the customer
  = Airlines are still operating on marginal profits.

Revenue Management Optimization Problem

selling the **right inventory unit** to the **right type of customer**, at the **right time**, and for the **right price**



Source : Own illustration

Differential pricing and potential revenue losses

Goal:
Maximization of the Expected Revenue

Revenue Management Optimization Problem

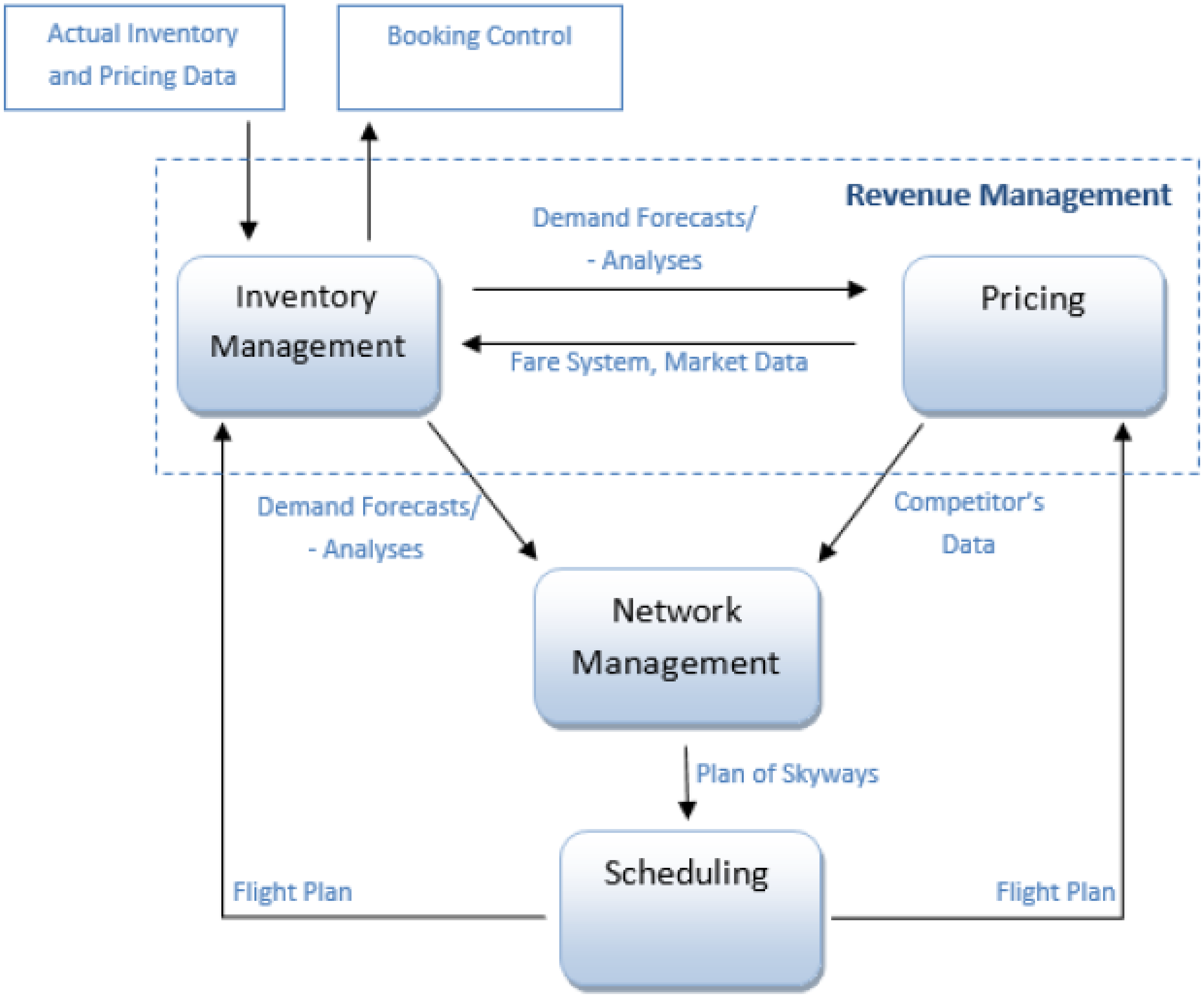
selling the **right inventory unit** to the **right type of customer**, at the **right time**, and for the **right price**

$$
\begin{aligned}
\max_{x} \quad & Proceeds \\
\text{s.t.} \quad & x_j \leq (Available\ Capacity)_j \\
& x_j \leq \textstyle\sum_i (Predicted\ Demand)_{ij} \\
& x_j \geq 0
\end{aligned}
$$

$$Proceeds = \textstyle\sum_{i,j} (Revenue)_{ij} \cdot x_{ij}$$

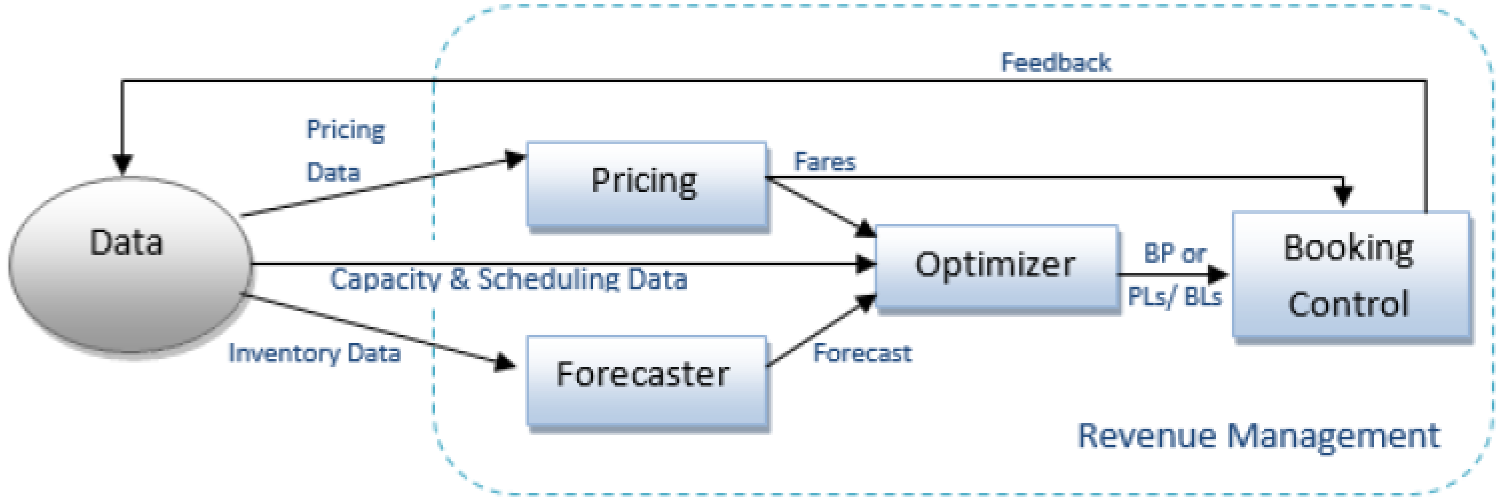
x … number of accepted booking request
j … the leg-index
i … the index of the customer segment
[cancellation are excluded]

Simplified scheme of the profit management of an airline



Source : Own illustration

Simplified scheme of the procedures in a RM system



Source : Own illustration

Tasks of RM:

1. Prediction of real-time customer demand
2. Optimization of offered price and product availability

Model Assumptions

- Over-proportionate high fixed costs (independent from the service delivered),
  - Example: In 2013 despited the proceedings in efficient operations and engines, the portion of costs for fuel compared to an airlines total operating costs has risen to more than 30%.
- And very low variable costs (additional costs for carrying one more passenger as long as there is an empty seat in the airplane)
- **Limited capacity:** C homogeneous units of a perishable resource (unused capacity will result in a loss of value after the departure)
- Reservation of products is possible over a limited time period
- A natural segmentation of the market caused by various customer preferences is possible
- The demand does not depend on the booking policy and is modeled as an independent random variable

Capacity-Based Booking Control

- Optimizing profits through a tactical availability control for a given fare structure,
- Meaning: For a given set of fixed prices an airline calculates the optimal capacity allocation

Static Model

- After ADA, when the need for intelligent booking control policies first appeared, static approaches were developed.
- 70% of actual operating airlines are using a static inventory control (according to B. Vinod)
- Prefered by segment-based carrier
- Idea: based on a given fare structure and the predicted demand, the available capacity is distributed among the fare classes such that the resulting revenue is maximal
  Control the inventory by regulating the demand through limiting the availability of fare classes/ products
- Model assumption:
  - Strictly product-sensitive demand
  - No cannibalization between different fare classes
  - customers request arrives sequentiell ordered by ist value

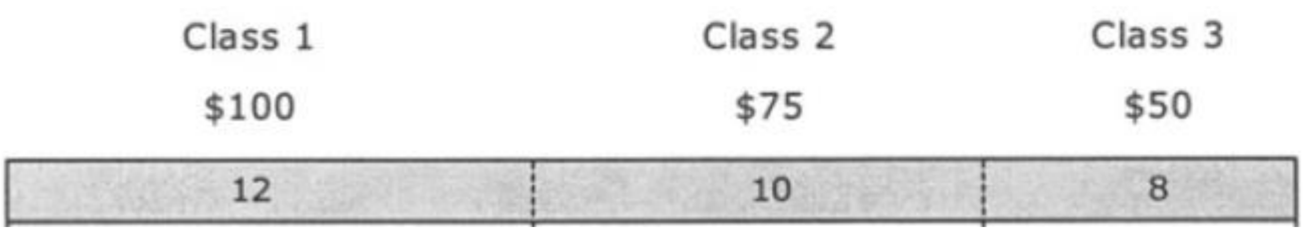
Static Model

Partitioned booking limit

- is defined for every single class and represent the maximum number of capacity units which are available for sale in this particular class

Nested booking limits

- offer an alternative approach by avoiding the rejection of high-value booking requests if capacity is still left in lower booking classes
- allow the access of booking requests to the booking limit of the corresponding class and to the booking limits of all lower classes



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Partitioned protection level

- is the amount of capacity which is reserved for the sale in this particular booking class

Class 1	Class 2	Class 3
\$100	\$75	\$50
12	10	8

Static Model

Partitioned booking limit

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Nested booking limits

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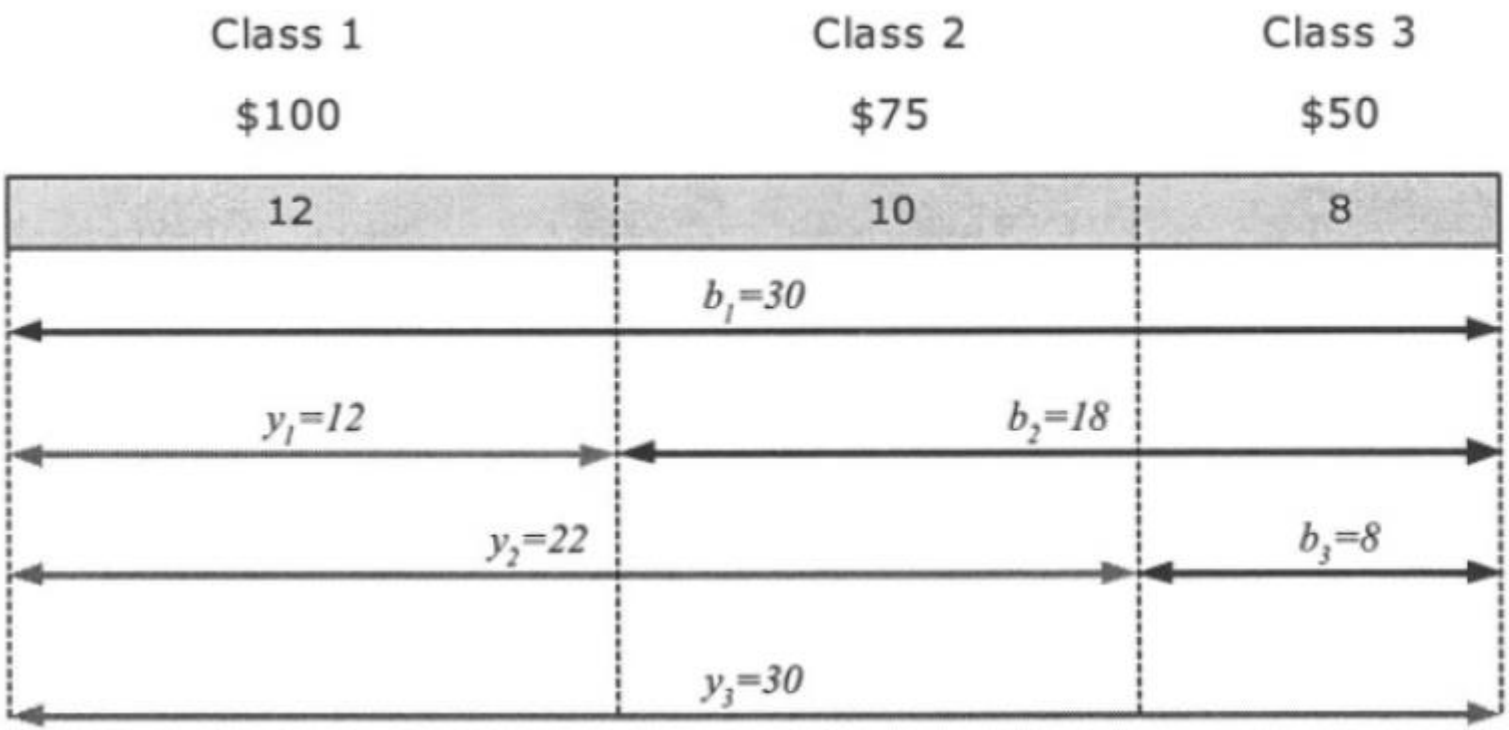
Partitioned protection level

- is the amount of capacity which is reserved for the sale in this particular booking class
- partitioned protection level of a class is equal to its partitioned booking limit

The relationship between nested booking limits (b) and nested protection levels (y)



Source : Garrett J. Van Ryzin and Kalyan T. Talluri. *The Theory and Practice of Revenue Management*. Springer Science & Business Media, Berlin and Heidelberg, 2004.

Static Model: Littlewood‘s Rule

- Ken Littlewood was the first who came up with the idea of a revenuebased booking control
- Littlewood himself criticized that every existing research paper to the best of his knowledge only focused on maximizing the load factor of a plane without considering the revenue
- restricted his analysis on two products that use the same resource, no cancellation, no overbooking
- price product 1 > price product 2
- assume that the demand for product 2 arrives first

- The decision problem described by Littlewood deals with the question of how many requests for product 2 should be accepted while saving as much capacity as is probably needed to satisfy the demand for the high-yield product 1?

Static Model: Littlewood‘s Rule

- Formally, this means we are accepting request for the low-yield product as long as the realized revenue for the sale is higher or equal to the expected revenue when keeping this capacity unit until requests for high-yield products start arriving

$$p_2 \geq p_1 \cdot \mathbb{P}(D_1 \geq x)$$

- Accordingly, for the optimal protection level *x** it holds true that selling capacity as product 2 is an optimal decision as long as there are at least *x* + 1 capacity units left, otherwise reject all request for product 2 and wait for the high-yield requests for product 1.

$$p_2 < p_1 \cdot \mathbb{P}(D_1 \geq x^*) \quad \text{and} \quad p_2 \geq p_1 \cdot \mathbb{P}(D_1 \geq x^* + 1)$$

Static Model: Expected Marginal Seat Revenue (version a)

- P. Belobaba focused on the question: How many capacity units should be protected against low-revenue requests to retain them for possible high-revenue requests at a later stage in the booking horizon?
- In doing so he applied Littlewood's Rule to successive pairs of booking classes and computed the amount of capacity reserved for a high-yielded class by summarizing the individual protection levels
- price product 1 > price product 2 > … > price product n
- j > k … are product indices

$$p_j < p_k \cdot \mathbb{P}(D_k \geq y_k^j) \quad \text{and} \quad p_j \geq p_k \cdot \mathbb{P}(D_k \geq y_k^j + 1)$$

$$\hat{y}_j = \sum_{k=1}^{j} y_k^{j+1}.$$

Example: EMSR-a

Class j	Revenue$_j$	Exp. demand$_j$ (μ_j)	Variance$_j$ (σ_j^2)
A	50	4	2
B	40	9	3
Q	15	25	5

- The task is to find the optimal capacity allocation for a total capacity of 20 seats (C = 20) and the given data set, assuming the demand to be normally distributed.

$$p_j < p_k \cdot \mathbb{P}(D_k \geq y_k^j) \quad \text{and} \quad p_j \geq p_k \cdot \mathbb{P}(D_k \geq y_k^j + 1)$$

$$\hat{y}_j = \sum_{k=1}^{j} y_k^{j+1}.$$

Static Model: Expected Marginal Seat Revenue (version a)

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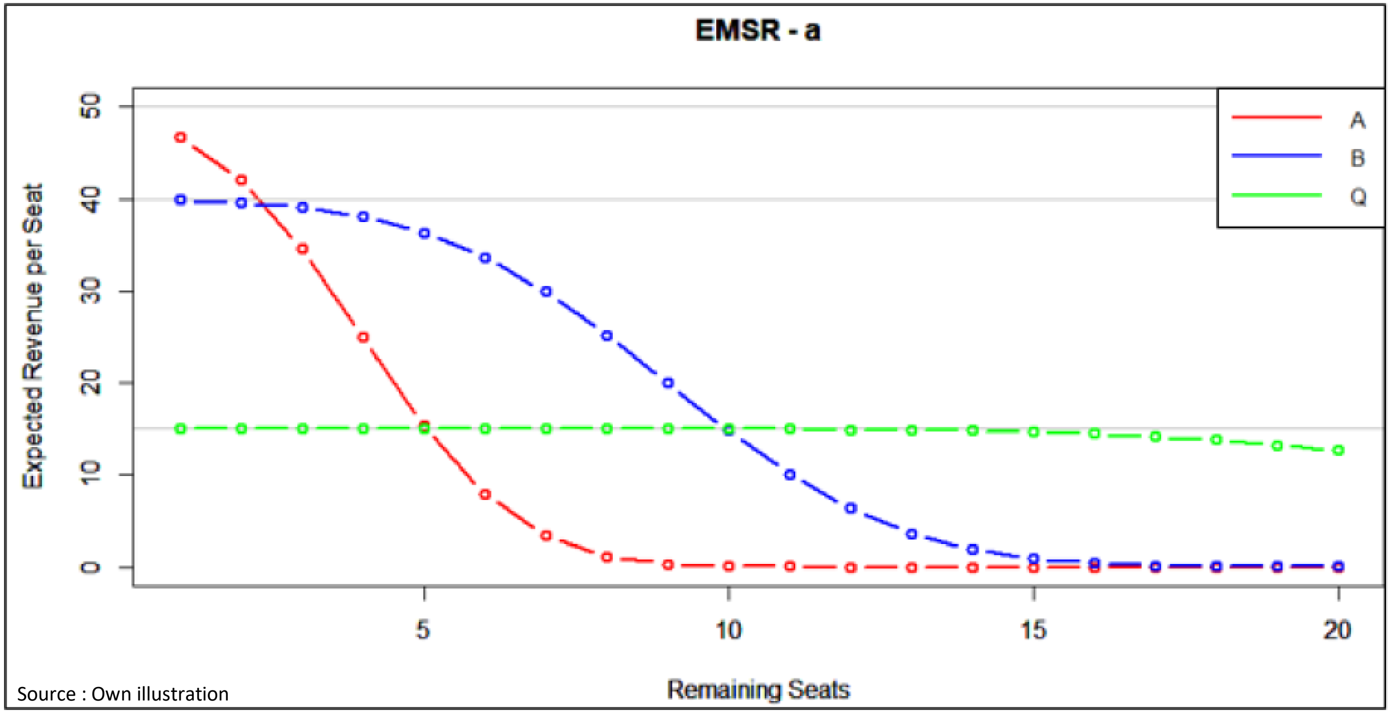

Class j	Revenue$_j$	Exp. demand$_j$	Variance$_j$	y_j^Q	y_j^B
A	50	4	2	5.049	2.317
B	40	9	3	9.956	—
Q	15	25	5	—	—

Dynamic Model

- Prefered by network carrier, who trys to include synergistic effects between different air routes caused by passengers traveling via an intermediate airport
- Idea: use dynamic optimization to determine a marginal price for each seat, then a fare is offered as long as it exceeds the marginal value of the actual inventory unit
- Model assumption:
  - Strictly price-sensitive demand
  - no assumptions about customers arrival order

Dynamic Model

Bid Price (BP) is defined

- as the net value for a specific seat on a particular flight,
- as the minimum acceptable fare,
- as an estimation of the marginal coast for the consumption of the next unit of the capacity resource, and therefore
- as a threshold price for the acceptance of a booking request

PRINCIPLE OF OPTIMALITY.

"An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision. "

- Bellman 1957 -

Dynamic Model

$$V_t(x) = \sum_j p_{jt} \cdot \max\{ r_j - [V_{t-1}(x) - V_{t-1}(x-1)], 0 \} + V_{t-1}(x)$$

$$V_0(x) = 0, \quad p_{0t} = 1 - \sum_j p_{jt}$$

$$\boldsymbol{BP_t(x) = V_{t-1}(x) - V_{t-1}(x-1)}$$

x … available capacity
j … the product-index
t … time
r … expected proceeds for selling product j
p … probability of selling product j at time t
V … expected revenue

Quiz

Answer the following questions!

- What happens to the Bid Price if the Demand is increasing?
- What happens to the Bid Price if the Capacity is decreasing?
- What happens to the Bid Price if the Fare is decreasing?
- What is the seat index and how it influences the Bid Price?
- How does the Bid Price Curve change over time?
- Which is the highest value the Bid Price can have in a particular class?
- Can you find protection levels with the Bid Price approach?

Complete the following sentences.

- If we have overcapacity (LF < 100%),
  then the BP is … important because … !
- If the expected load factor is higher, the Bid Price … .

Take-Aways


Photo by Ashim D’Silva on Unsplash

Airline Revenue Management

- Airlines face the stochastic, time dependent, and heterogeneous demand for an almost homogeneous product by implementing segment-oriented price differentiation.

- The availability control provided by static models is, compared to dynamic approaches, less responsive to the actual market situation. This implies, when using static approaches, to adapt the booking control policy to actual inventory needs, a resolving of the complete optimization problem is required.

- Network carrier prefer a Bid Price control policy, because for connecting flights the opportunity costs of not having this seat on each leg can be easily calculated by summing up all Bid Prices for each used resource.