Part II

Airline Pricing

Christophe BONTEMPS

AIRLINE PRICING

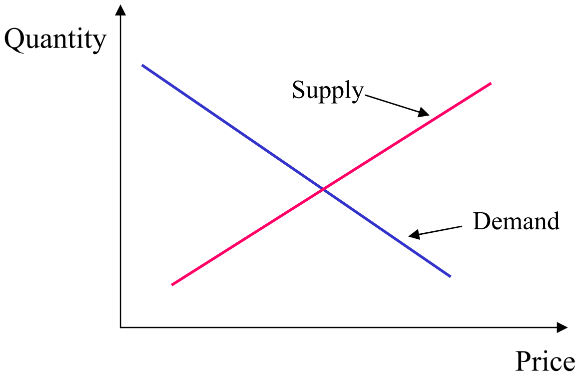
- General pricing principles
  - the role of prices
  - consumer surplus
  - price discrimination
- Yield management
  - definition and basics
  - prices and price discrimination
  - fare classes management

General pricing principles

Basic economic principles, price discrimination

Prices ? What for ?

- To adjust demand and supply



- Example : Prices varying with time can be used to adjust a moving demand to a rigid (limited) supply

A simple case : homogenous good and unique price

- Consider a good with no variation in its composition nor its quality (homogenous)
- Suppose there is a unique price for this good on the market : The seller cannot discriminate among customers and change the price according to their purchasing power
  - This is the case for most goods, with a labeled price

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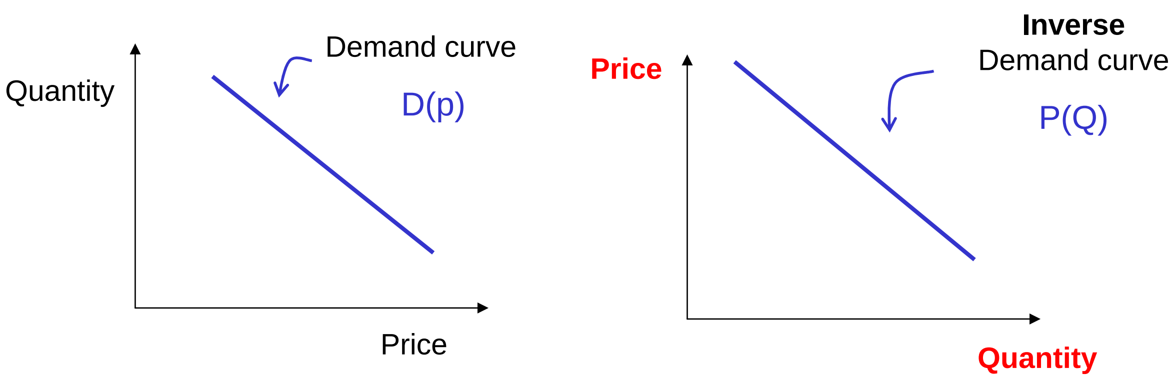
Demand curve and inverse demand



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Price and perfect competition

- Assume that each producer has a no influence on the price p* .
  - he is a « *price-taker* »
- The producer chooses his production level Q* in order to maximize his profit :

$$\text{Max } \Pi(Q) = p^* \times Q - c(Q)$$

$$\text{thus: } c'(Q^*) = p^*$$

- The price on the market, p* , is equal to the marginal cost of production

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Price and monopoly

- Consider the extreme case of a monopoly. The producer chooses its price $p^m(Q)$ and its production Q^m as a function of the demand function
- D(p), is reverse to p(Q)

$$\text{Max } \Pi(Q) = p^m(Q) \times Q - C(Q)$$

$$\text{so : } C'(Q^m) = p^m(Q) + p^{m\prime}(Q^m) \times Q^m$$

- The marginal cost is equal to the marginal revenue
- The price is higher and the quantity produced lower.

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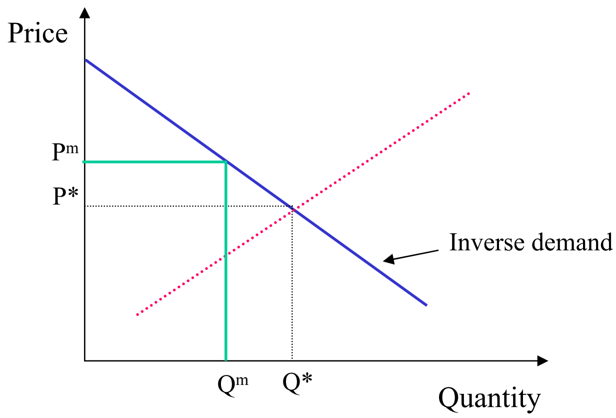
Price and monopoly



One can show that : $p^m > p^*$

$Q^m < Q^*$

and $\Pi(Q^m) > \Pi(Q^*)$

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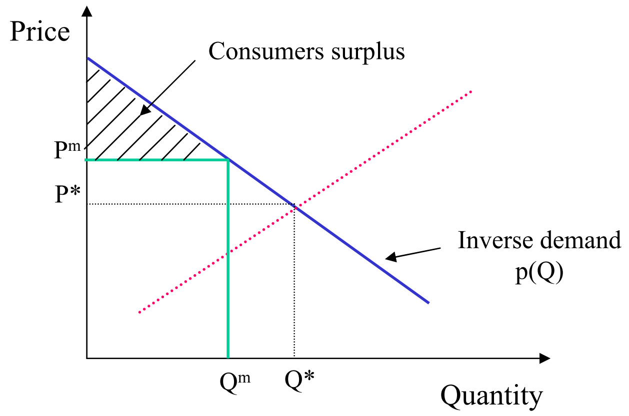
Price and imperfect competition

- In a case of limited competition (restricted number of producers), the situation lies between the previous cases :
  - Each producer has some flexibility (limited by other producers) for defining its price
- The price lies between the previous prices.

Consumers surplus



The "*consumers surplus*" is the area lying between the price paid and the inverse demand curve. This is a measure of the consumers "*welfare*" .

The surplus is higher under perfect competition : A firm with a market power tries to extract the consumers rent.

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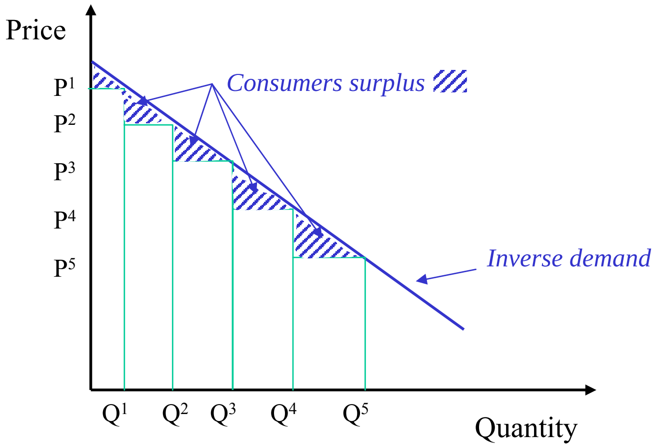
Complex case: heterogeneous goods and/or price discrimination

- There may be difference in the composition or in the quality of the goods (or services), leading to a price discrimination
- There may be price discrimination with homogenous goods in the case where firms are allowed to discriminate among there customers.
- The aims are :
  - surplus extraction (private sector)
  - redistribution (government social measures)

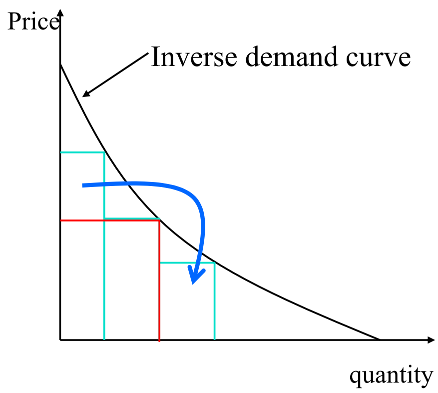
Surplus extraction

- By setting different prices for different quantities, the producer may extract some money to the consumers surplus



Redistribution

Part of the money extracted from the surplus by setting higher prices for some consumers can be used to define lower prices for others



Price discrimination : definition

There is price "discrimination" if the differences in the prices paid by two customers are not justified by the costs differences for the service or the good

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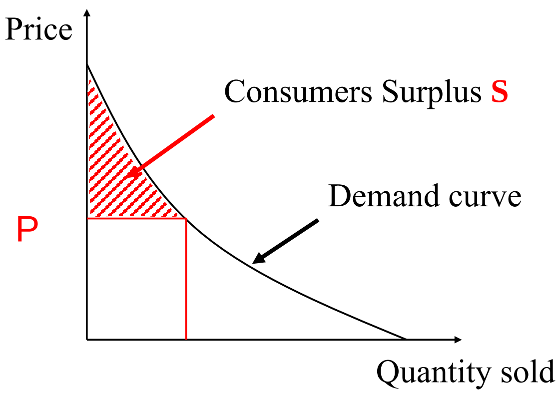
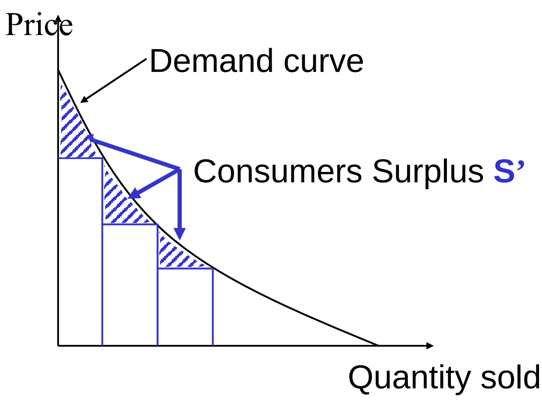
Price discrimination : illustration

Uniform Price p



Different levels of prices



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Price discrimination: conditions

Conditions :

- The firm must have a sufficient market power (monopoly or oligopoly)
- Few trade possibility between customers
  - The good is non resalable between customers
- The consumers preferences must be different

Three types of price discrimination

- 1st degree : Perfect discrimination
  - Theoretical case where the willingness to pay is perfectly known
- 2nd degree : discrimination using filtering and auto-selection.
  - *Ex:* Quantity rebates
- 3rd degree : discrimination using signals on consumers preferences
  - *Ex* : Discount for students, family, etc.

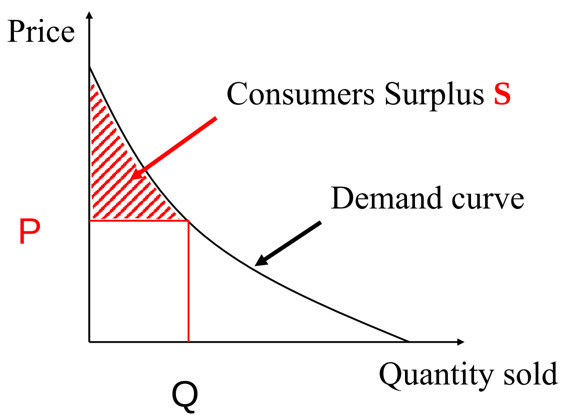
Price discrimination : Consequences

- The firms extracts parts of the consumers surplus.
- The global effect on the total welfare is not clear
  - The surplus is extracted
  - Results in different prices allowing people with less WTP to travel
- Very often, there is a redistribution from the consumers with a low price elasticity (high revenues) to the consumers with a high price elasticity (low revenues)
  - The surplus variation depends on the quantity produced.

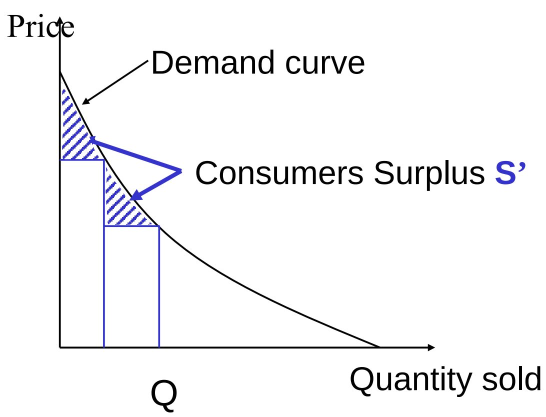
The consumers surplus is lower…

S > **S'**

Uniform Price p



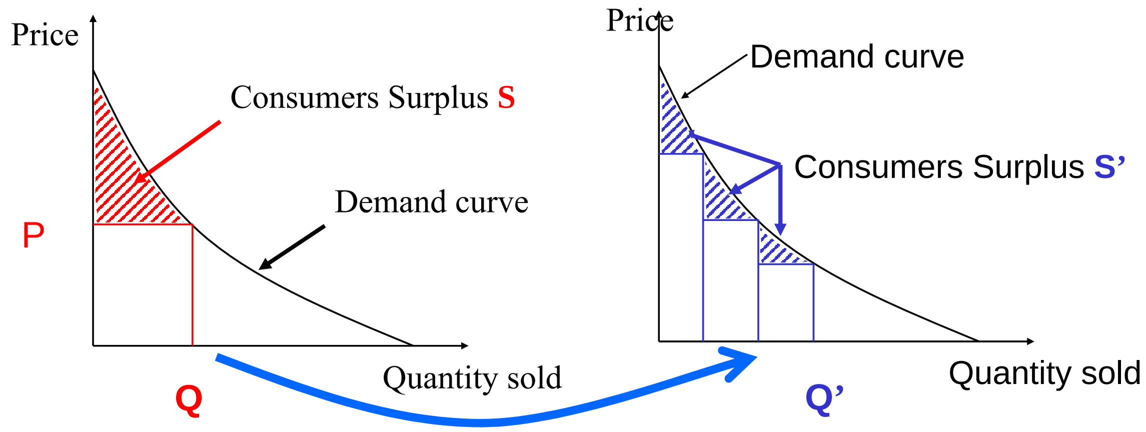
Different levels of prices



…unless the quantity produced is changed

Uniform Price p

Different levels of prices



Price discrimination and quality

- One shows that the quality provided for people with the lowest quality valuation is lowered: the firm use the lowest quality goods to segment the market

"What the company is trying to do is prevent the passengers who can pay the second-class ticket fare from traveling third-class; It harms the poor, not because it wants to hurt them but to frighten the rich."

(Dupuit 1849)

Price discrimination in practice

- Very popular in transportation
  - Motorway tariffs: the cars pay for the trucks (Political decision)
  - Airline and railway pricing : Price discrimination and "revenue management"
  - Air traffic control pricing : small planes get subsidies from bigger ones
- Can be criticized when the purpose is consumers surplus extraction without competition on the market

Practical example

(G. Van Ryzin)

- 5 customers with different valuations (unobservable)
- 2 flights with a 3 seats capacity
- The maximum obtainable revenue is R=800+700+400+300+200=2400€

800€ 700€ 400€

300€ 200€

Departure 8:00 AM **Departure 11:00 AM**

Case I

– Price is set to 700€ for each flight
– Revenue =2x700=1400
– 58% of Maximum Revenue

Priced out

400€

300€ 200€

700€ 800€

Departure 8:00 AM

Departure 11:00 AM

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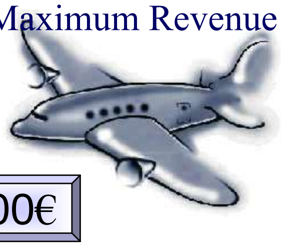
Case II

– One introduce discrimination through restrictions
– Price :
  - 700€ no restrictions
  - 400€ if Saturday night stay
– Revenue =2x700+400=1800€
– 75% of Maximum Revenue

Priced out

300€ 200€

The second plane is still empty



400€

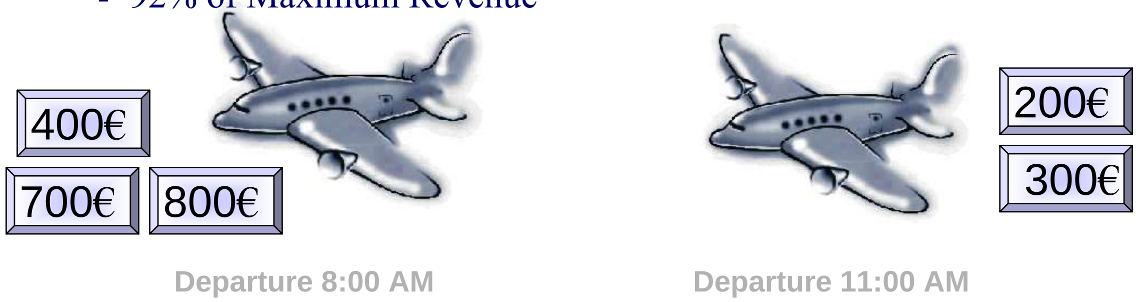
700€ 800€

Departure 8:00 AM

Departure 11:00 AM

Case III

- One introduce capacity controlled discount Price :
  - 700€ no restrictions
  - 400€ if Saturday night stay
  - 200€ available on second, less demanded plane
- Revenue =2x700+400 +2x200=2200€
  - 92% of Maximum Revenue



« Revenue Management »

Revenue optimization methods

From load- factor maximization to revenue optimization

- "Revenue management" is a method for maximizing the total revenues of an airline. The goal is different from "simply" have the highest load factor.
  - The term "yield management" is improper but originally and currently used
- This tool can be used as soon as
  - The service provided is perishable
  - Capacity is quite fixed
  - Demand is flexible

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Origins of the «Revenue Management»

- The "Airline Deregulation Act" in 1978 (USA) states the freedom of competition principle
- Freedom of fares
  - Price discrimination is possible
  - New entrants
  - The airlines in activity develop computer programs managing the information and improving marketing strategies
- The US airlines have invented the "revenue management".

Principles of «Revenue Management»

- Simultaneous control of supply and demand in order to maximize revenues.
  - Demand is controlled through fares adjustments (p_i) and bookings
  - Supply q_i is monitored through the available capacity Q

$$\max_{p_i, q_i} \Pi(p_i, q_i) = \sum_i p_i \times b(p_i, q_i) - C(Q)$$

$$\text{such that} \quad \sum_i q_i \leq Q$$

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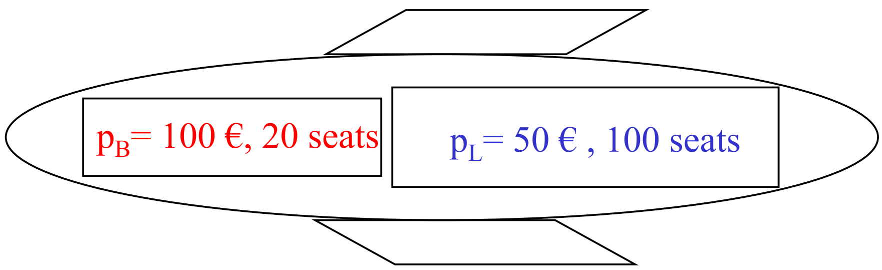
A simple example

- Two fares
- One airplane with a fixed configuration

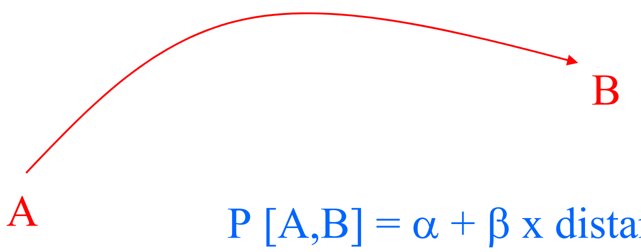


Questions :

- How to set the prices ?
  - Knowledge of the demand
  - Compare with other airline (market survey)
  - Costs
- How to discriminate between consumers ?
  - Using restrictions on the service provided
- How to set the capacity of each class ?
  - Accurate demand forecast within each class of price

Prices before and after deregulation

- Before
  - Prices fixed by the regulator ; two classes (economic and first)
  - Prices linked to distance



$$P [A,B] = \alpha + \beta \text{ x distance } [A,B]$$

- After
  - Prices disconnected to costs

Profit maximization before and after deregulation

- Before

$$Max\,\Pi(p_f, q_f, p_e, q_e) = \underset{q_f, q_e}{Max}(p_f \times q_f + p_e \times q_e - C(Q_e + Q_f))$$

$$such\ that\ q_f \leq Q_f\ \ and\ \ q_e \leq Q_e$$

  - competition through frequencies and service to stimulate demand

- After

$$Max\,\Pi(p_f, q_f, p_e, q_e) = \underset{p_f, q_f, p_e, q_e}{Max}(p_f \times b_f(p_f, q_f, p_e, q_e) + p_e \times b_f(p_f, q_f, p_e, q_e) - C(Q_e + Q_f))$$

  - Competition through prices and restrictions

Prices: current situation

- Prices are adjusted following :
  - Competition (oligopolies !)
  - Passengers characteristics or preferences (willingness to pay)

But...

- Prices are disconnected to costs
  - Prices are defined by strategic consideration (fidelity, image)
  - The marginal cost is “fuzzy”
  - Can airlines completely ignore the cost constrains ?

Restrictions : the "packages" price -ticket

Airlines propose "menus" or packages with prices and services characteristics

- Numerous price class : F, J, S, B, M, Q… corresponding to prices
- Characteristics : Origin-destination, but also services and restrictions (date restrictions, no date change, week-end included,)

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Restrictions examples

- Third degree discrimination (objective characteristics):
  - Student prices, family prices, retired people discount
- Second degree discrimination
  - Week-end special fares, non-refundable tickets, no date change, special tariff if ticket bought X-days in advance…
  - Goal : discriminate among users considering their willingness to pay, or their constraints (time, schedule)

How to set prices ?

- Consumers preferences are represented through their "utility" U for a service s at a price p(s)

$$U_i = \theta_i \cdot s - p(s)$$

- The trade-off between price and restrictions has to be well studied
- Competition outlook
  - The competition limits the airline power on the consumers
- Rules of separability, flexibility, degressivity and readability

Pricing rules

- Separability
  - Services and prices have to be different enough
- Flexibility
  - Ability for the airline to change fares
- Degressivity
  - Ability to "surclass" with limited additional cost
- Readability
  - The tariff has to be clear for consumers

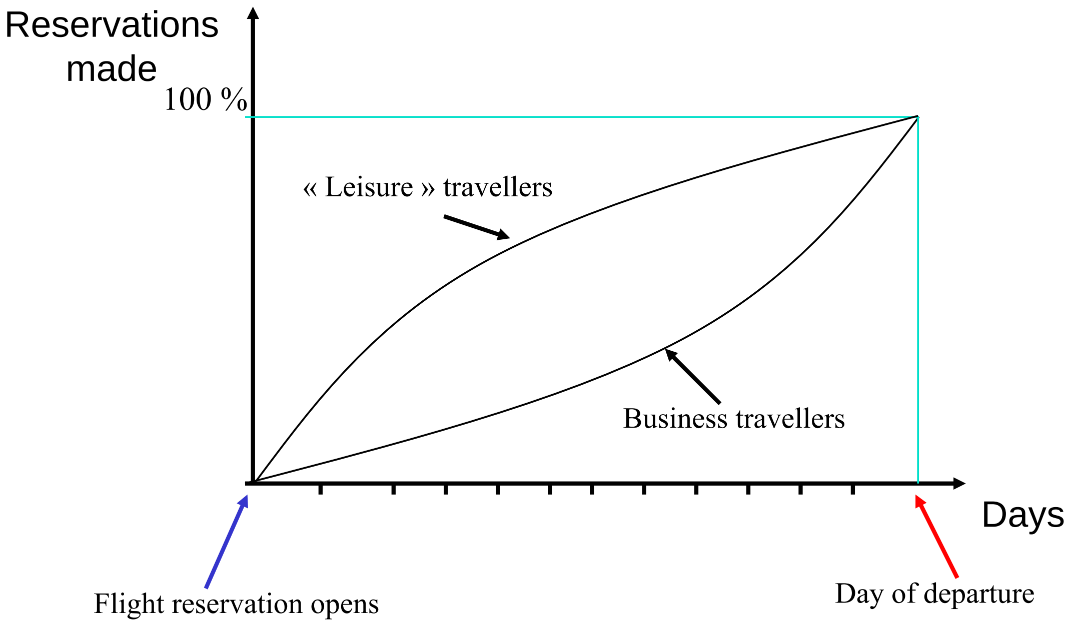
Price and discrimination

- The different services sold distinguish through prices and quality
  - The restrictions imposed are variation (degradation) of the service quality
- Airlines discriminate their consumers using quality and not quantity
  - It is really discrimination since the variation in quality has a cost quite small for the airline, compared to the variation of the price (price ratio 1 to 10)

How to organize the booking with different classes

- Booking behavior
- Trade-off between «spoilage» and «spill»
- Quota capacity computation on a two class example
- Dynamic allocation
- Revenue management over a Network
- Overbooking , no-show and go-show
- Consumers behavior models

Booking behavior



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Booking behavior

- The "high fare" passengers reserve lately their seat.
  - Schedule change, uncertainty
- The "low fare" book rather in advance
  - Tendency is also linked to restrictions
- The problem is to protect the "high fare" seats until few days before departure, without losing the "low fare" ones (change of airline !)

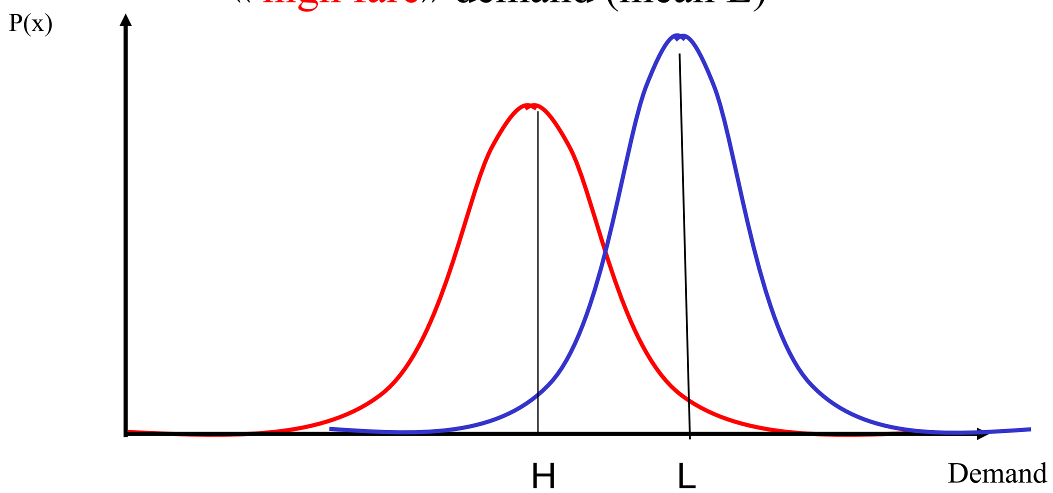
Managing this Trade-off is not simple !

The core of the trade-off problem

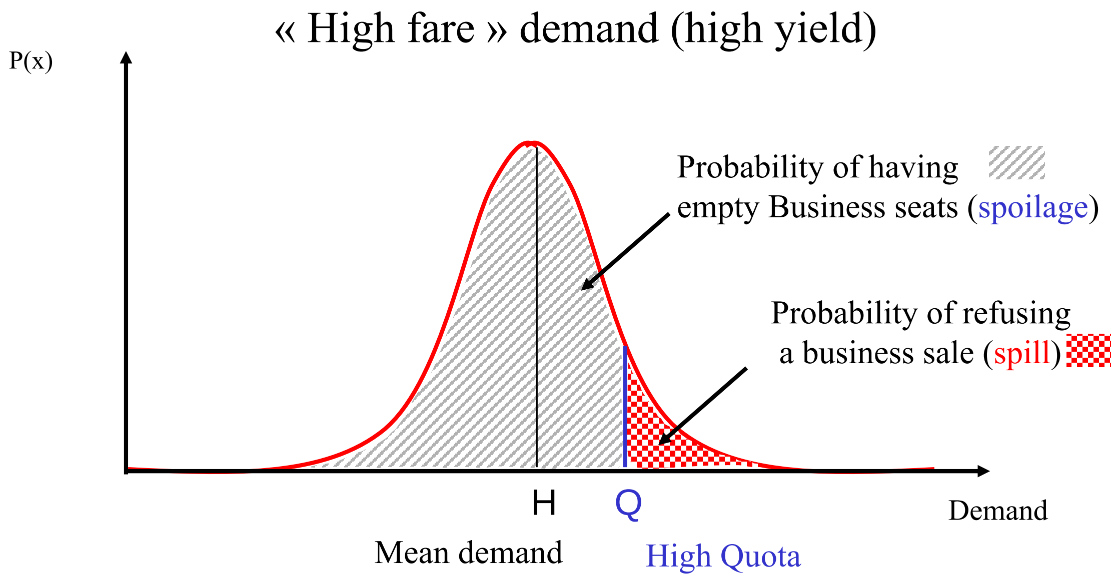
- The number of seats asked within each class (demand) is by nature random
- Let's consider a "high fare" demand with mean H (let's assume a normal distribution)
- If one allocate a small quota (less than H), there is a risk of rejecting "high fare" consumers (Spill)
- If one allocate a high quota (more than H), there is a risk of empty seats (spoilage).

Distribution of demand

« low fare » demand (mean H) and
« high fare» demand (mean L)



Distribution of demand



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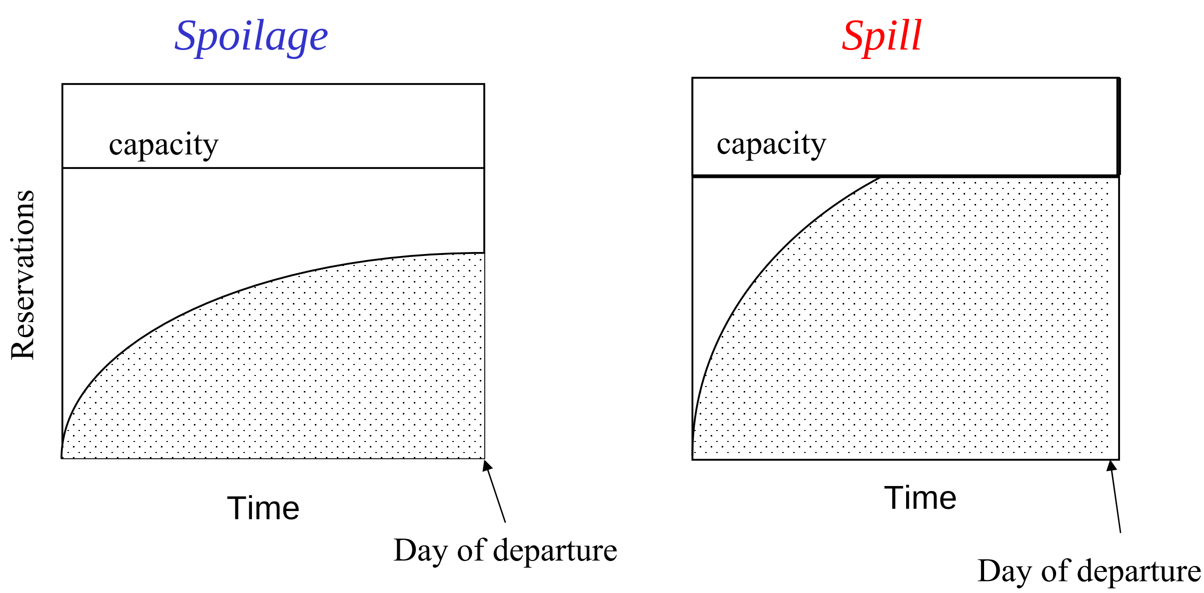
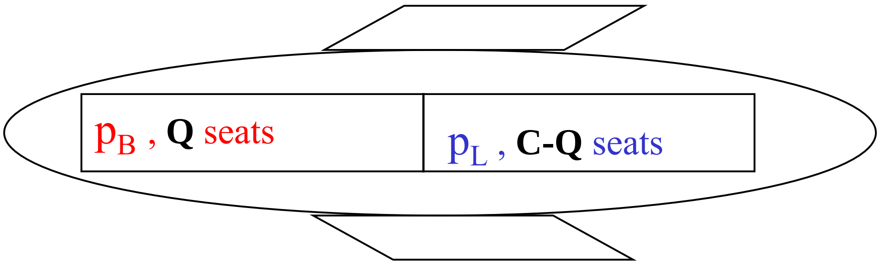
Spoilage and Spill



A simple example with two independent classes

- One airplane with a fixed configuration C= total capacity
- Two fares PL (leisure) and PB (business)
- The demand distributions for the two classes xL and xB are assumed to be known fL(x) and fB(x).



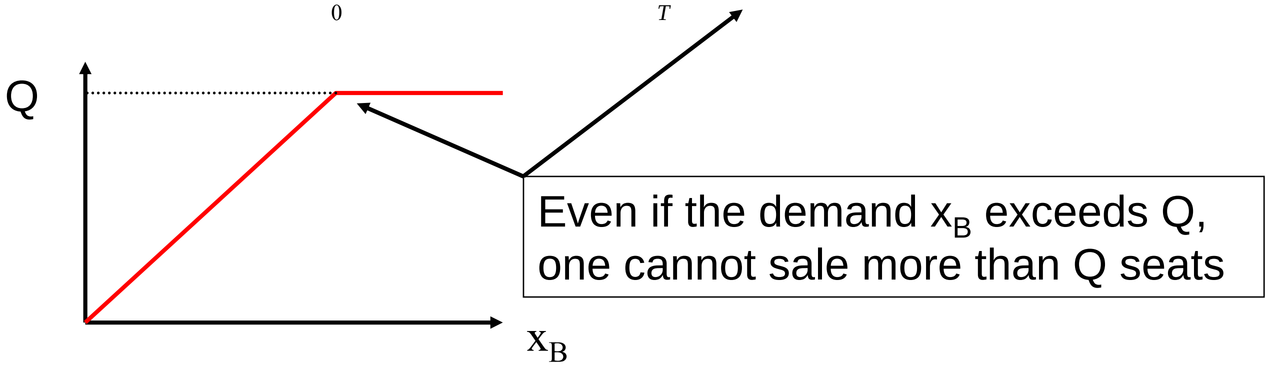
Determination of the Quota (Q) for two independent classes

- The problem is to compute the value of Q such that the global revenue is maximum
- The global revenue is not deterministic, for each class one has the expectation of the revenue (linked to the probability of asking a seat = demand distribution)
- Global revenue is = $E(R_L) + E(R_B)$

Determination of the Quota (Q) for two independent classes

- Let's compute the expectation of revenue for the business class

$$\mathrm{E}(R_B) = \int_0^Q p_B \cdot x_B . f_B(x_B).dx_B + \int_T^\infty p_B \cdot Q . f_B(x_B).dx_B$$



Determination of the Quota (Q) for two independent classes

- Total revenue = $\mathrm{E}(R_B) + \mathrm{E}(R_L)$

$$\mathrm{E}(R_B) = \int_0^Q p_B \cdot x_B . f_B(x_B).dx_B + \int_Q^\infty p_B \cdot Q . f_B(x_B).dx_B$$

$$\mathrm{E}(R_L) = \int_0^{C-Q} p_L \cdot x_L . f_L(x_L).dx_L + \int_{C-Q}^\infty p_L \cdot (C-Q) . f_L(x_L).dx_L$$

Determination of the Quota (Q)

- The derivation relative to the unknown variable Q gives

$$\frac{d\mathrm{E}(R)}{dQ} = p_B \int_Q^{\infty} f_B(x_B).dx_B \; - p_L \int_{C-Q}^{\infty} f_L(x_L).dx_L = 0$$

$$\boxed{p_B \int_Q^{\infty} f_B(x_B).dx_B \; = p_L \int_{C-Q}^{\infty} f_L(x_L).dx_L}$$

What does it means ?

- Let's define EMSV = "expected marginal seat value"

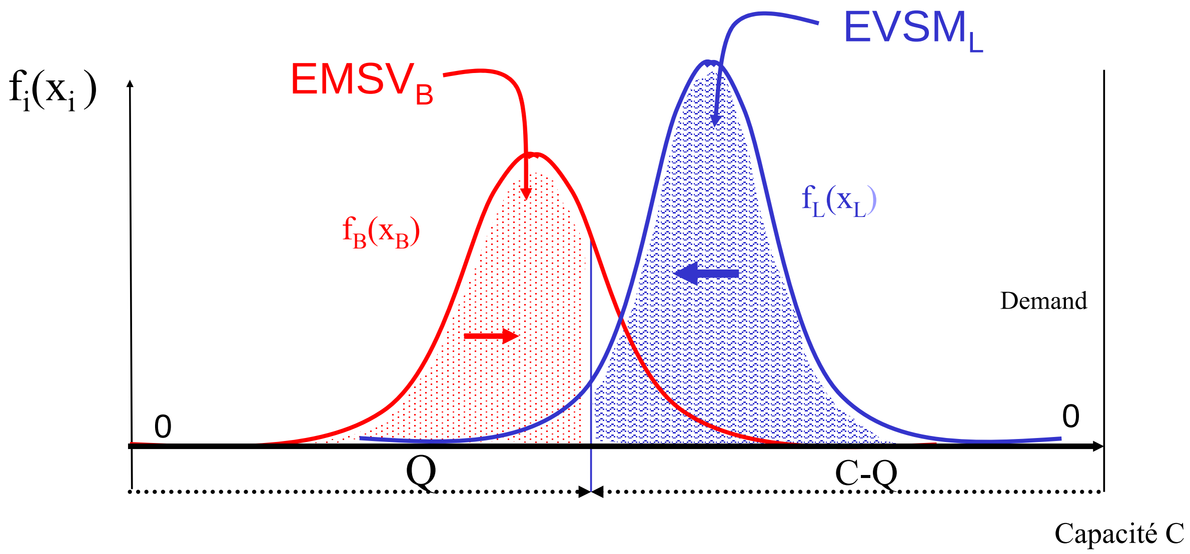
$$EMSV_i = p_i \int_{S_i} f_i(x_i).dx_i$$

$$i = B, L$$

- In the case of independent (partitioned fare) classes, the EVSM must be equal in each class.

$$\mathrm{EMSV_B} = \mathrm{EMSV_L}$$

Graphical illustration



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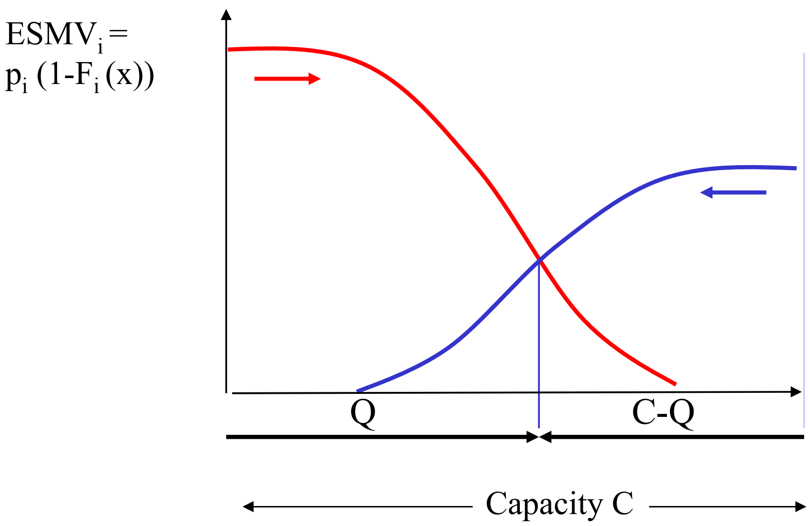
Graphical illustration



Remarks

- In this simple case, the formula for the optimal quota :

$$p_B \int_Q^{\infty} f_B(x_B).dx_B = p_L \int_{C-Q}^{\infty} f_L(x_L).dx_L$$

depends on

  - The distributions of the individual demands in each class
  - The prices for each class

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Dynamic allocation

- The demands are estimated for each flight, using information on the booking and on past experiences, the computation of Q is done using the previous formula

But…

- The computation has to be revised if the booking behavior shows that the demands are not the one expected
- The demands (and Q) have to be re-estimated using actualized estimations of the demands.
  - In practice, one only revise the allocation if the reservation are not conform to the expectations.

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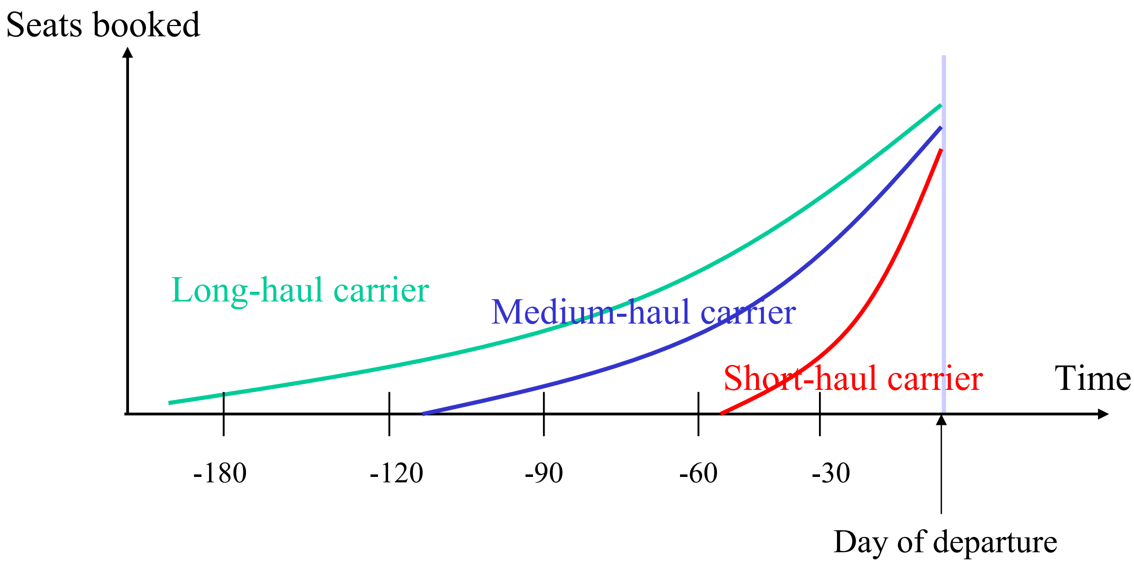
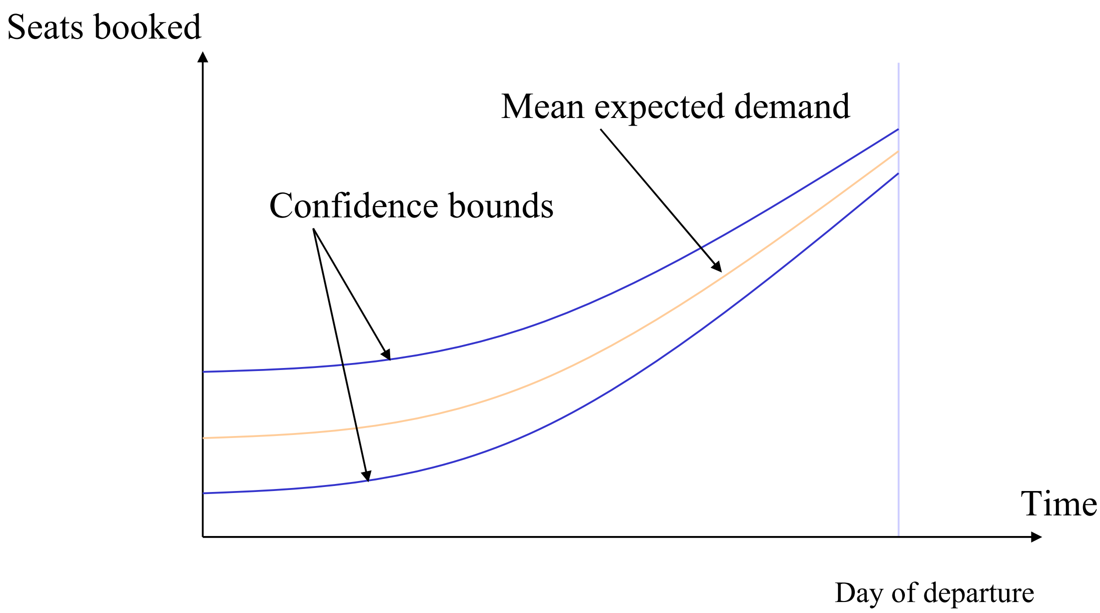
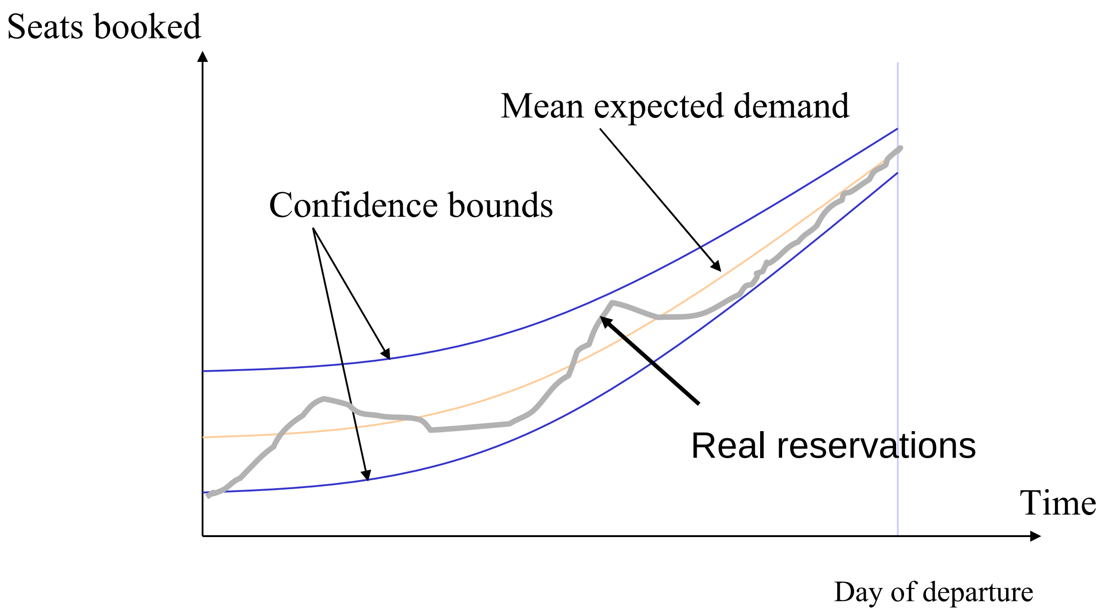
General shape of booking over time



Dynamic of booking



Dynamic of booking



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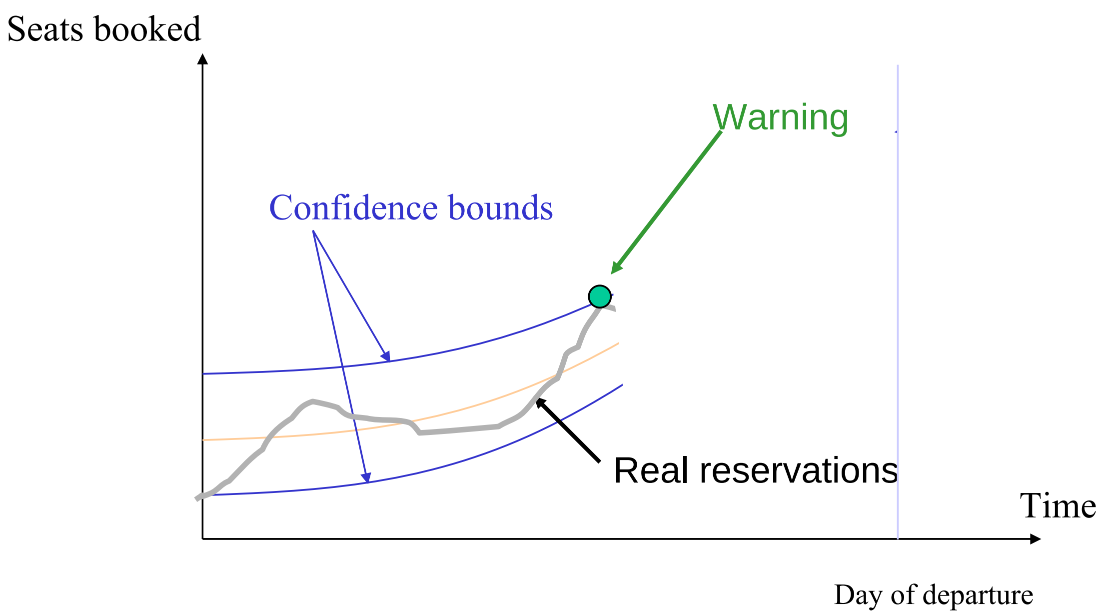
Dynamic of booking



New allocation

- When a warning appears, one must re-allocate the seats within each class according to the new (unexpected) demand
  - Revise the demand forecasts
  - Can be done manually or almost automatically
- There may be systems with systematic re-allocation for specific dates (J-90, J-45, J-30…). For each date, one compare the real and expected demand in each class

Limits I

We have assumed in the previous example, the complete independence of the demands, but :

- Some passengers are ready to switch from one class to another (if their first choice is full)
- One must introduce a probability of accepting a fare P_B if one has been rejected in a P_L fare class
- Complex statistical computations + estimation of this probability = experimental stage

Limits II

We have assumed that a reserved ticket is a sold ticket, but :

- Not true for tickets with possibility of change in the date of departure, or refundable
- Some people simply don't take the plane they've booked and cancel their flight at the last minute « No-show »
- On the contrary, some people do not reserve « Go-Show »

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« No-shows »

- Some passengers with a reservation do not board and do not cancel their reservation (about 15%)
  - This proportion of no-shows is higher for the most demanded flights
  - % of "no show" is decreasing with flight distance
  - Frequent pattern for "business" travelers (multiple reservations)
  - Shadow reservations on several airlines
- One solution is to «over-book» in order to fill the empty seats even if there are no-shows

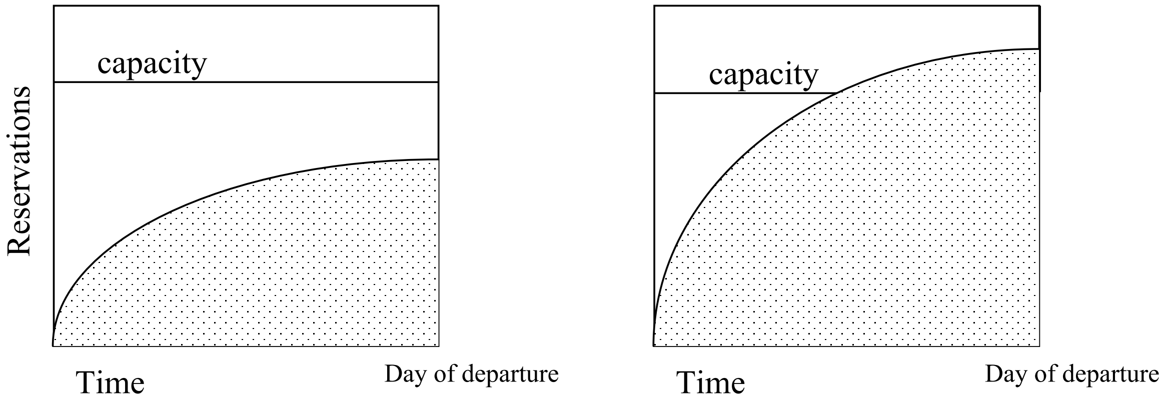
« Go-shows »

- This pattern is the inverse of the previous : people arrive at airport without any reservation
- May compensate the no-shows deficit
- Induces a lot of uncertainty in airline revenue maximization program

"over-booking"

- Used to balance the cancelled reservation and the "no-shows"
  - Tours operators may use these empty seats
- Trade-off between two risks
  - Risks of empty seats if one accept few reservations (*spoilage*)
  - Risk of having too many people for the capacity available (*denied access*)

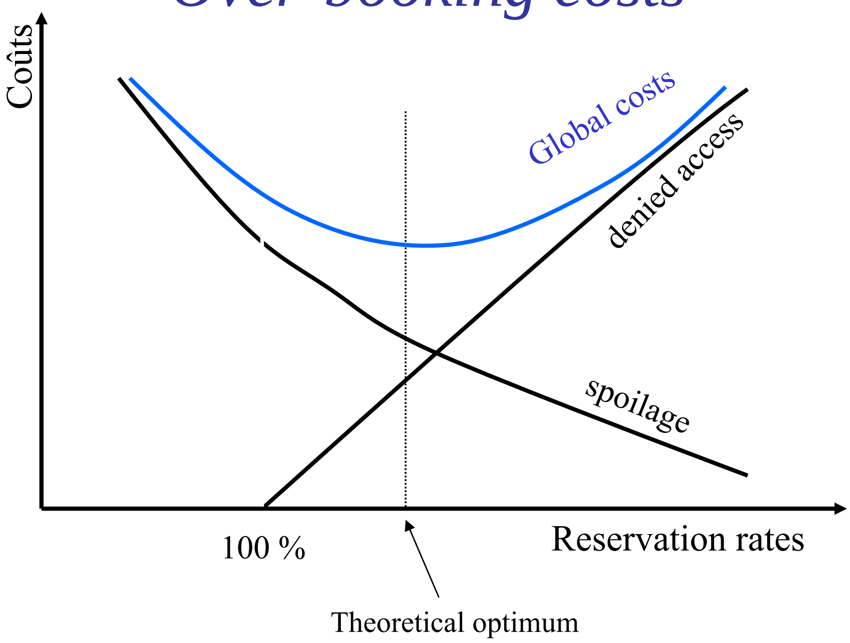
Spoilage and denied access



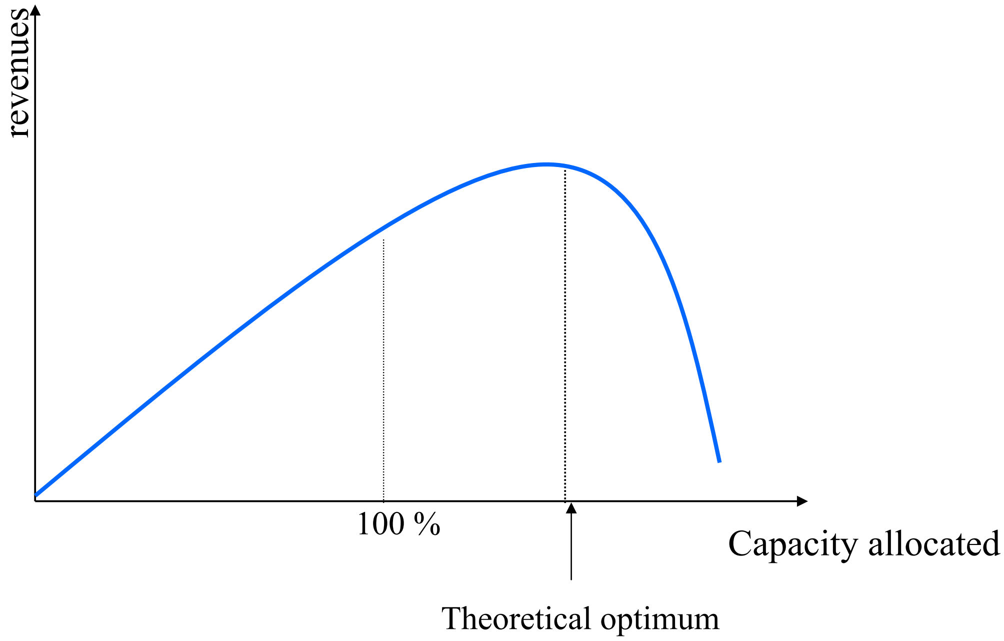
Spoilage

denied access

Over-booking costs



Over-booking benefits



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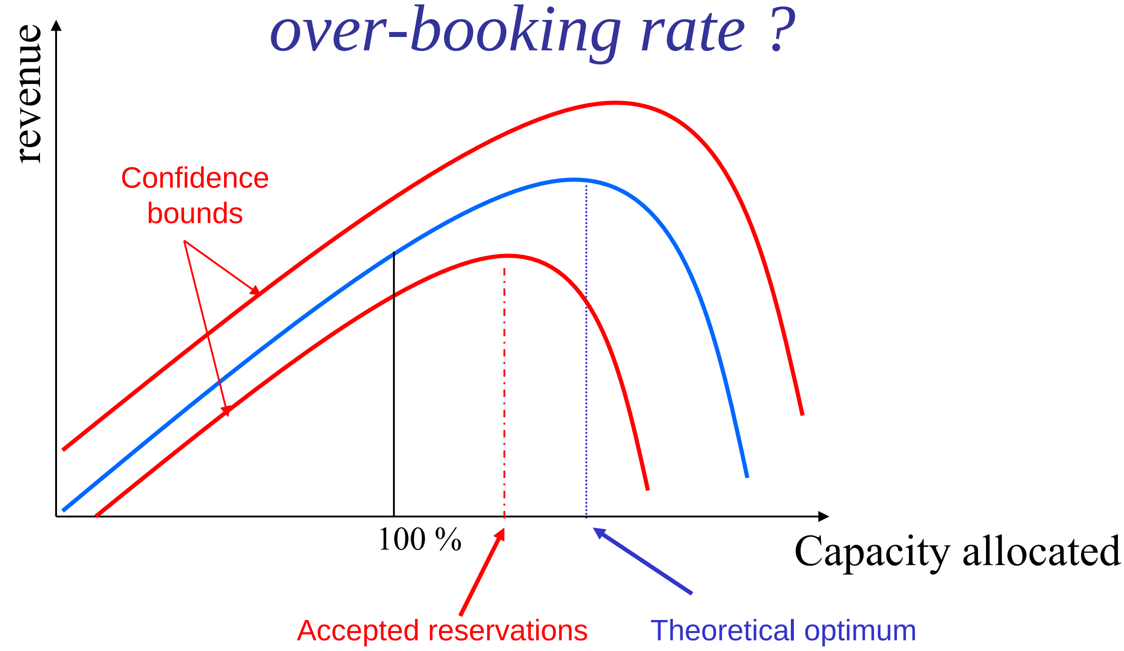
How to compute the over-booking rate ?

- One accept over-booking in a class *i* as long as
  - The "Expected Marginal Seat Value" for class *i* is greater than the expected cost of a denied access :

$$\text{EMSVi} \geq k \times Pr$$

  - Where *k* is the cost of a denied access, and *Pr* the probability that the final demand exceeds the capacity
- One may be able to know the average denied access as a function of the reservation rate and its variance
- In the practice it is quite hard since the «no-shows» are hard to forecast with precision (high variability)

How to compute the over-booking rate ?



Managing denied access

- Usually airline managers are trying to find volunteers for a flight change using financial compensations
- Otherwise, denied access will be applied in priority to “low fare” passengers (difficult in practice)
- The airline must propose a denied access traveler a posterior flight

Final remarks

- Revenue management has changed the pricing and management of airlines but also the travelers behavior
  - Some last minute seats are available and people may know that feature
  - Booking behavior may be affected by a too complex mechanism
- The system is quite complex, demand is still a random variable
  - There is a cost to such a mechanism (experts, software, management)
  - There is also a cost in making mistakes !! (Denied access, over-booking or empty seats)
- Major airlines propose such a complex mechanism that pricing seems fuzzy to travelers (readability problem)

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Final remarks

Low cost airlines propose a simple revenue management scheme

- « Our fares change as seats are sold » easyjet
- Price increases with time
- Very clear pricing
- Very cheap management system based only on booking dynamic over time
- Still this is revenue management but not based on restrictions
  - very few “no-show” since the tickets are non refundable

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