

# DOC-Assessment Method

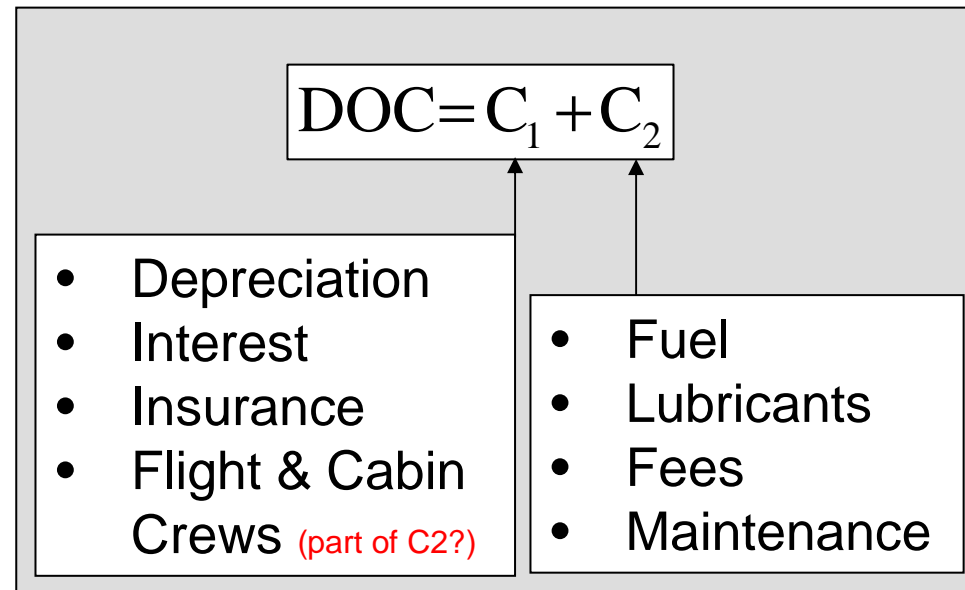
## ▶ TU Berlin – DOC Method

- A simplified DOC Model
- JAVA DOC Applet

J. Thorbeck

(with remarks in red by D. Scholz)

- ▶ Two elements are required for the most simple DOC model :
  - C1: Route independent (fixed) Cost
  - C2: Route dependent (variable) Cost



- ▶ **COC = DOC without capital cost (depreciation, interest, insurance)**
- ▶ How does a typical cost scenario look like?
- ▶ Which parameters do we need to know in order to use that formula?
- ▶ Which parameters have to be assessed from statistical data?

- ▶ Simplifications:
- ▶ All **route independent cost** are primarily based on the aircraft size and its respective operational empty weight (OEW)
- ▶ The major element is the **capital cost** which can be assumed to be a linear function of the OEW (if the aircraft market influence is considered negligible) and thus

$$C_{CAP} = [P_{OEW} \cdot (OEW - W_{Eng} \cdot N_{Eng}) + W_{Eng} \cdot N_{Eng} \cdot P_{Eng}] \cdot (a + f_{Ins})$$

$$\text{with } a = IR \cdot \frac{1 - f_{RV} \cdot \left(\frac{1}{1+IR}\right)^{DP}}{1 - \left(\frac{1}{1+IR}\right)^{DP}}$$

with a: Annuity factor

$P_{OEW}$ : Price per kg OEW (Structure/Systems/Equipment, 1150 €/kg)

$P_{Eng}$ : Price per Engine Weight (2500 €/kg)

IR: Interest rate (5%)

DP: Depreciation period (14 years), also mortgage payback period

$f_{RV}$ : Residual value factor (Residual value / aircraft price, 10%)

$f_{Ins}$ : Insurance rate (0,5%)

$N_{Eng}$ : Number of Engines

$W_{Eng}$ : Weight per Engine

- ▶ That annuity formula, which is based on a modified mortgage equation, addresses both yearly depreciation and interest
- ▶ The reason for the a.m. modification is to include the residual aircraft value at the end of the depreciation period into the capital cost, which is occasionally meaningful
- ▶ That does assume that an operator is buying an aircraft at a constant price per kg and spends the corresponding capital cost constantly per year all over the depreciation period
- ▶ Insurance cost are also proportional to the aircraft price

- ▶ **Personnel cost** are assumed to be route independent because an airline has to provide a sufficient number of crews to ensure flight operations over the entire service time and therefore are proportional to the payload
- ▶ 50 passengers per Flight attendant (certification requirement) and 100 kg per passenger are assumed
- ▶ Flight crew cost are considered constant per year and result from the sum of the average of a commander and a first officer salary and thus

$$C_{Crew} = CC \cdot \left( S_{FA} \cdot \frac{MPL}{5000} + S_{FC} \right) \quad \text{or:} \quad \boxed{C_{Crew} = CC \cdot (S_{FA} \cdot n_{FA} + S_{FC})}$$

$n_{FA} : \text{one for each 50 pax}$

with  $n_{PAX}$ : Maximum number of passengers; MPL: max. payload  
 $S_{FA}$ : Average yearly salary of a flight attendant (60.000 €/year)  
 $S_{FC}$ : Average yearly salary of a cockpit crew (300.000 €/year for 2 pilots)  
 CC: Crew Complement (Number of crews per Aircraft, 5) (independent of utilization?)

- ▶ The **route independent cost** per year therefore sum up to

$$C_1 = C_{CAP} + C_{Crew}$$

- ▶ Within the **route dependent cost** lubrication cost can be assumed to be of minor order of magnitude compared to the **fuel cost** and can be addressed by a minor correction of the fuel price
- ▶ The fees are comprising payload dependent **handling fees** and maximum take-off weight (MTOW) dependent **ATC fees** and **landing fees**
- ▶ The **route dependent yearly cost** thus be calculated by

$$C_2 = FC \cdot \left( P_F \cdot TF + P_{PL} \cdot PL + P_L \cdot MTOW + f(R) \cdot R \cdot \sqrt{\frac{MTOW[to]}{50}} + MC \right)$$

with  $P_F$ : Fuel price [0,5 €/kg] ([see p. 13](#))  $P_L$ : Landing fees [0,01 €/kg]

TF: Trip fuel [kg]

$P_{PL}$ : Handling fees [0,1 €/kg]

PL: Payload [kg]

FC: Yearly flight cycles

FH: Yearly flight time

R: Range [km]

MC: Maintenance cost per flight cycle

$f(R)$ : Range dependent ATC price factor (1,0 for domestic Europe, 0,7 for transatlantic flights, 0,6 for far east flights (only half of landings at European airports))

- ▶ **Fuel cost** are based on the trip fuel (e.g. from payload range diagram)
- ▶ The fourth term represents the EUROCONTROL formula for **ATC-fees**. The price factor considers the fact that the price scenarios are varying strongly for each continent (or even region)
- ▶ **Landing fees** are charged on basis of aircraft MTOW and **Handling fees** on Payload whereas **ATC fees** are based on both the secured flight distance (Range) and the discounted (square root!) MTOW
- ▶ **Maintenance cost split into**
  - **flight cycle dependent cost**, reflecting primarily structural fatigue and overhaul burden,
  - **flight hour dependent cost**, which take into account primarily wear and the associated line maintenance work and
  - **calendar time dependent cost**, which is a constant share reflecting for example the rectification of corrosion during overhaul, the latter being route independent and thus considered as constant

- ▶ The following method is an approximation for maintenance cost per flight cycle is given by the sum of three parts:
  - $MC_{AF,MAT}$ : Airframe material maintenance cost (repair and replacement)
  - $MC_{AF,PER}$ : Airframe personnel maintenance cost (inspection and repair)
  - $MC_{ENG}$ : Engine total maintenance cost

$$MC_{AF,MAT} = OEW[to] \cdot (0,21 \cdot FT + 13,7) + 57,5$$

$$MC_{AF,PER} = LR \cdot (1 + Burden) \cdot \{(0,655 + 0,01 \cdot OEW[to]) \cdot FT + 0,254 + 0,01 \cdot OEW[to]\}$$

$$MC_{ENG} = N_{ENG} (1,5 \cdot SLST[to] + 30,5 \cdot FT + 10,6)$$

$$MC = MC_{AF,MAT} + MC_{AF,PER} + MC_{ENG}$$

- ▶ with
  - Burden: Cost burden (2)
  - FT: Flight time
  - LR: Labor rate (50 €/h)
  - $N_{ENG}$ : Number of engines
  - SLST: Sea level static thrust of one engine [to]
  - OEW: Operating empty weight
- ▶ These empirical formulae include time dependent constant shares as well as burden reflecting fixed maintenance cost and administrative overhead



- ▶ A basic structure of a generic **utilization** formula is

$$FC = \frac{OT_{p.a.}}{(FT + BT)} = \frac{OT_{p.a.}}{\left(\frac{R}{v} + BT\right)} \quad \text{with} \quad OT_{p.a.} = POT_{p.a.} - DT_{p.a.}$$

with  $OT_{p.a.}$ : Yearly operation Time

$POT_{p.a.}$ : Potential yearly operation time ( $365 \cdot 24h = 8760$  h)

$DT_{p.a.}$ : Yearly forced downtime (2748,8 hours) consisting of

C-Checks (3,2 days p.a., 4 days per 15 month)

D-Checks (5,6 days p.a., 4 weeks per 5 years)

Repairs (2,6 days p.a., statistical average)

Night Curfew (7 days p.a., from 11:00 p.m. until 6:00 a.m. at operation days)

FT: Flight time

BT: Block time supplement per flight  
(1,83 hours (too high ?), statist. average)

R: Average stage length

v: Cruise speed

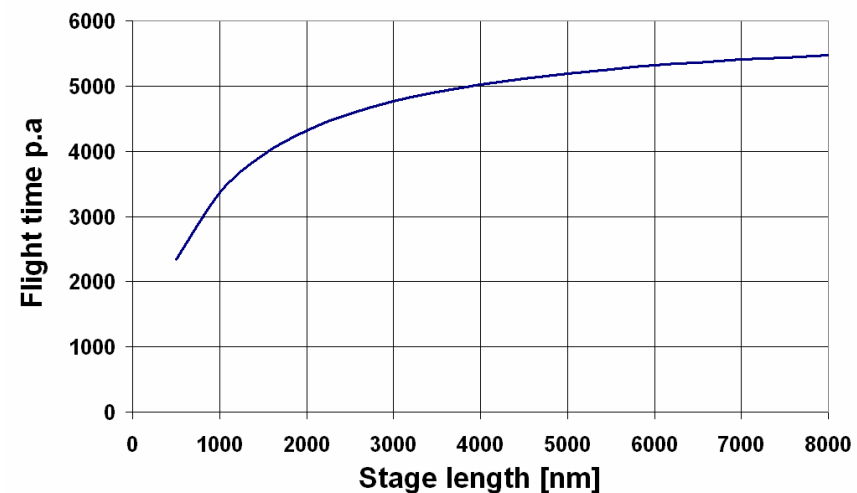
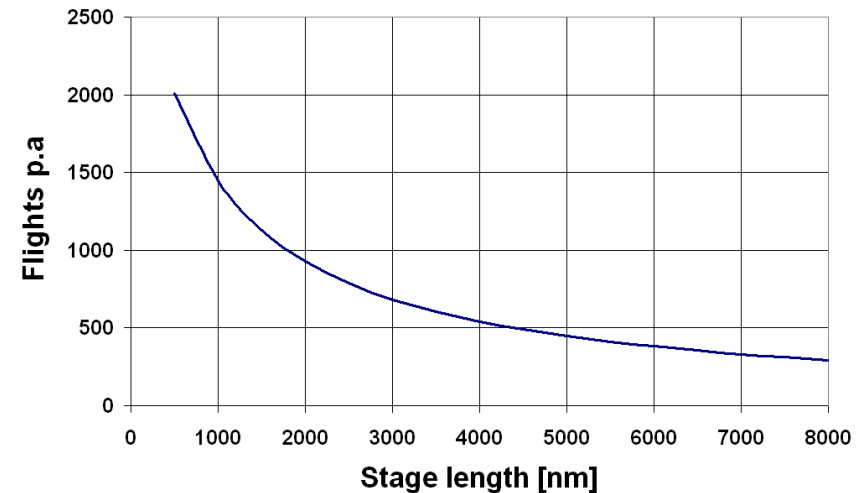
- ▶ Note: It is hereby assumed, that the flight is performed with constant speed, which is not the actual case (ref. climb/descent/approach segments)

- ▶ Statistical values for large airlines operating in the European scenario are
  - Average operation time: 6011,2 hours (Maintenance, night curfews)
  - Average block time increment: 1,83 hours
- ▶ With that the Utilization formula can be written

$$FC = \frac{6011,2}{\left( \frac{R}{v} + 1,83 \right)}$$

- ▶ The yearly flight time yields

$$\begin{aligned} FH_{p.a.} &= FC \cdot FT \\ &= \frac{6011,2}{1 + v \cdot \frac{1,83}{R}} \end{aligned}$$



- ▶ Only a limited number of parameters are necessary to calculate DOC
  - **Financial parameters** (Interest rates, depreciation period, residual value)
  - **Operational parameters** (Yearly flight cycles & downtime, block time supplement, crew salaries, crew complement, specific maintenance cost)
  - **Aircraft design weights** (MTOW, OEW, PL)
- ▶ Whereas financial and operational parameters can be obtained from statistical investigations, the aircraft weights have a flight physical origin
- ▶ For comparison purposes, the operational scenario described by the above figures can be set relatively arbitrary, however, within reasonable limits
- ▶ In order to adopt the method to a known result, the most uncertain parameters can easily be calculated by applying a non-linear optimization algorithm (e.g. EXCEL-SOLVER) to a least squares formulation of the error sum

## ► Consideration of additional cargo

– Method of freight equivalent passenger seats

- Cargo revenue from residual cargo payload at MZFW  
( $PL_{Max} - PL$ )

$$E_{CARGO} = FR \cdot (G_{N,max} - G_{PAX})$$

- Equivalent seat revenue

$$n_{PAX,Cargo} = \frac{E_{CARGO}}{E_{PAX}} \cdot R$$

–  $E_{Pax}$ : Revenue per seat and flight [€], 370 € (constant ?)

– FR: Revenue per freight-km [€/tkm], 0,07 €

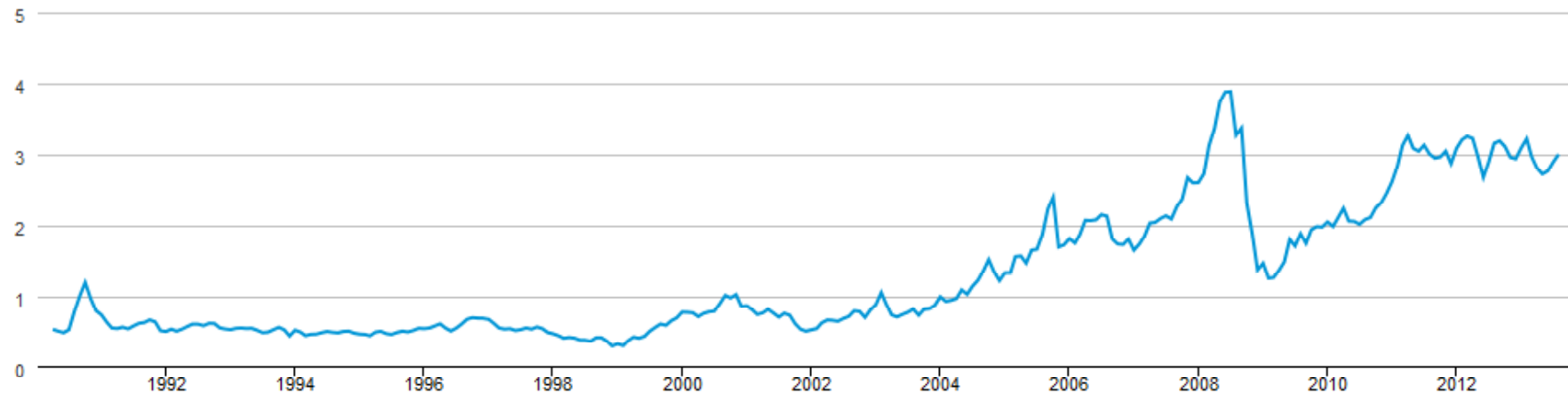
- DOC correction

$$\left( \frac{DOC}{SKO} \right)_{kor} = \left( \frac{DOC}{SKO} \right) \cdot \frac{n_{PAX}}{n_{PAX} + n_{PAX,Cargo}}$$

- ▶ Current kerosene price is about constant since 2011

U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB

Dollars per Gallon

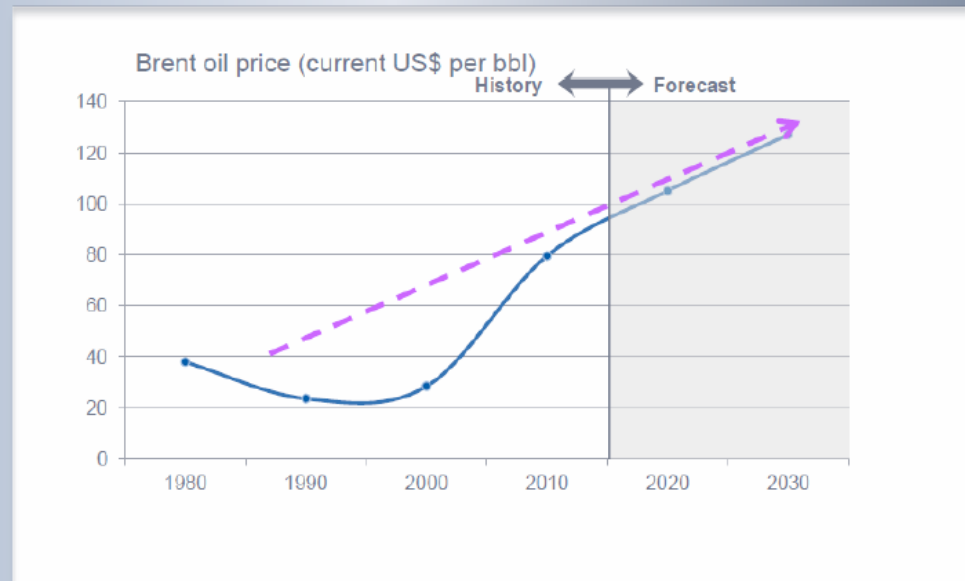


Current fuel price: 0.80 €/kg

- ▶ 3,7854 l/USgal; 0,8 kg/l; 1,3 US\$/€; “Into Plane Differential”: 0,05 US\$/kg
- ▶ The fuel price is higher than the fuel price on page 6

- ▶ The increase of kerosene price in the future is predicted by Airbus to be linear: 2 US\$/bbl/year
- ▶ Barrel: 1bbl (US) = 159 l; 1,3 US\$/€; 0,8 kg/l
- ▶ Future fuel price: current fuel price (2013: 0,53 €/kg) plus price increase

High oil prices here for the long-term



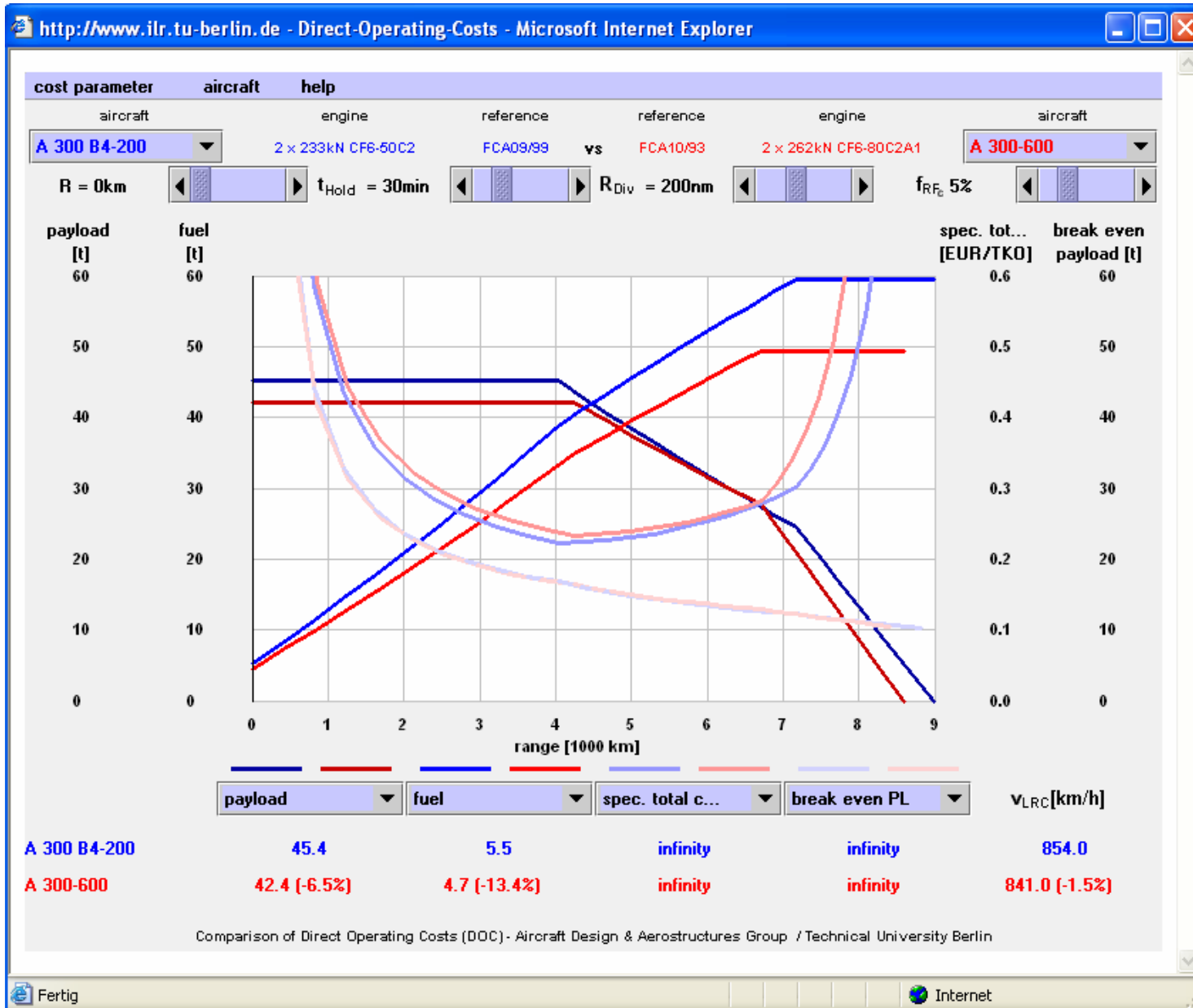
Source: IHS CERA, Airbus. Average price in the year displayed



© AIRBUS S.A.S. All rights reserved. Confidential and proprietary document.

0.012 €/kg/year

J. LEAHY. *Navigating the Future*. Global Market Forecast 2012-2031. Airbus, 2012



- ▶ The applet provides the following functions
  - Selection of two comparison aircraft out of an integrated aircraft data base
  - Defining a new aircraft by its design characteristics
  - Altering the DOC assumptions
  - Comparing the influence of a parameter change for a selected aircraft
  - Graphical representation of up to four of the following selectable parameters over the range axis:
    - Absolute DOC of components and resulting total
    - Relative DOC on TKO, Paxkm and km basis of components and resulting total
    - Payload
    - Break even Payload
    - Trip and reserve fuel
    - Flight time
    - Take of weight
    - Average mission weight
    - Productivity (per flight & p.a.)
    - Utilization (flight hours & flight cycles p.a.)
    - Payload factor



- ▶ For a proper comparative assessment of aircraft it is helpful to calculate and display also the break even payload BEPL
- ▶ For a given revenue rate (RR) in terms of €/TK the comparison of cost (DOC) and revenue leads directly to the break even payload (BEPL) because for break even the condition must be

$$\text{Revenue} = \text{DOC} \Rightarrow RR \cdot \text{BEPL} = \text{SMC} \cdot \text{PL} \Rightarrow \text{BEPL} = \frac{\text{SMC} \cdot \text{PL}}{RR}$$

- ▶ The area between the BEPL and PL line in the payload range diagram indicates the profitable domain of operations
- ▶ Below BEPL the operation is prone to financial losses
- ▶ The best result is achieved, if the aircraft is operated with maximum payload in the domain close to design range
- ▶ For testing of the a.m. formulae, a java applet has been supplied, which can be accessed via the internet under  
[http://www.luftbau.tu-berlin.de/menue/studium\\_und\\_lehre/java\\_applets/](http://www.luftbau.tu-berlin.de/menue/studium_und_lehre/java_applets/)