Chapter 18
Cost Analysis

RAND DAPCA IV Model for Aircraft First Cost

Used for both military and commercial cost models

Establish cost estimating relationships (CERs) for:

- Engineering hours (H_E)
- Tooling hours (H_T)
- Mfg. hours (H_M)
- QC hours (H_Q)

- Dev. support cost (C_D)
- Flight test cost (C_F)
- Mfg. material cost (C_M)
- Engine production cost (C_{eng})

Production Manufacturing Hours Learning Curves

$$2^{x} = 2\left(\frac{\%\text{learning curve}}{100}\right)$$

$$x = \frac{\ln\left(2 \times \left(\frac{\%\text{learning curve}}{100}\right)\right)}{\ln 2}$$

E.g. for 80% learning curve (typical)

$$x = \frac{\ln\left(2 \times \left(\frac{80}{100}\right)\right)}{\ln 2} = 0.678$$

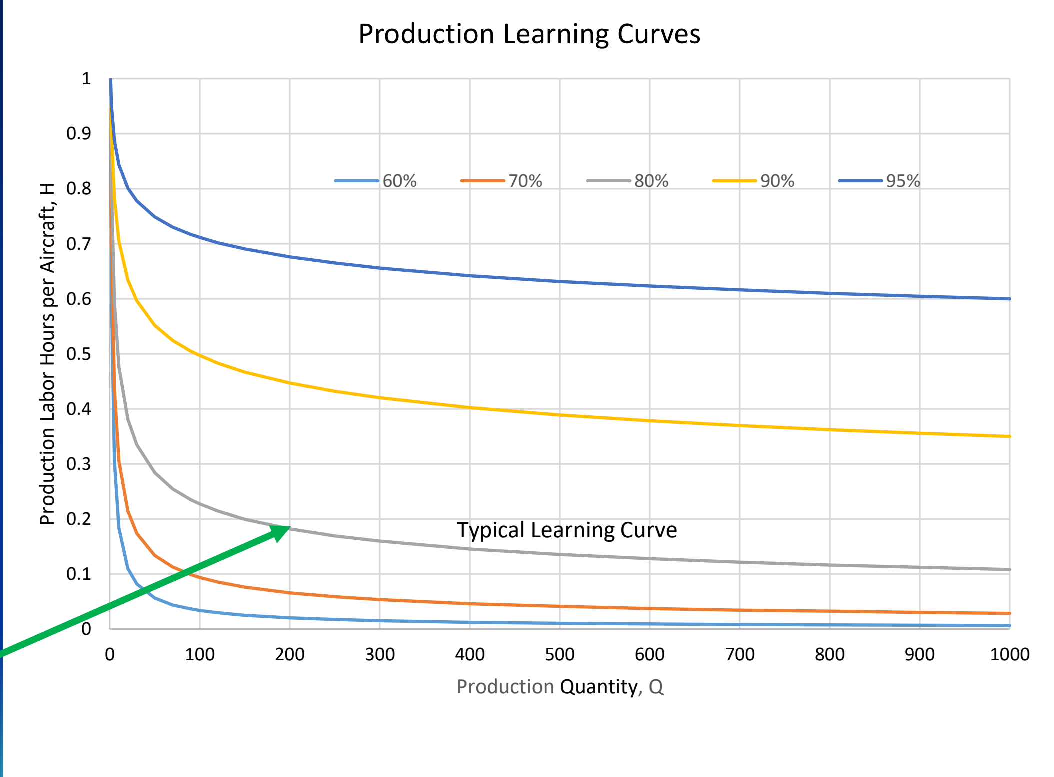
Say it takes 10,000hrs to make first aircraft

For $Q_1 = 1$ $H_1 = 10{,}000$

$$H = H_1\left(\frac{Q}{Q_1}\right)^{x-1}$$

Number of hours for 200th aircraft $(Q = 200)$

$$H_{200} = 10{,}000 \times (200)^{0.678-1} = 1{,}815 \text{ hrs}$$



Learning Curves (Log-log scale)

$$2^x = 2\left(\frac{\%\text{learning curve}}{100}\right)$$

$$x = \frac{\ln\left(2 \times \left(\frac{\%\text{learning curve}}{100}\right)\right)}{\ln 2}$$

E.g. for 80% learning curve (typical)

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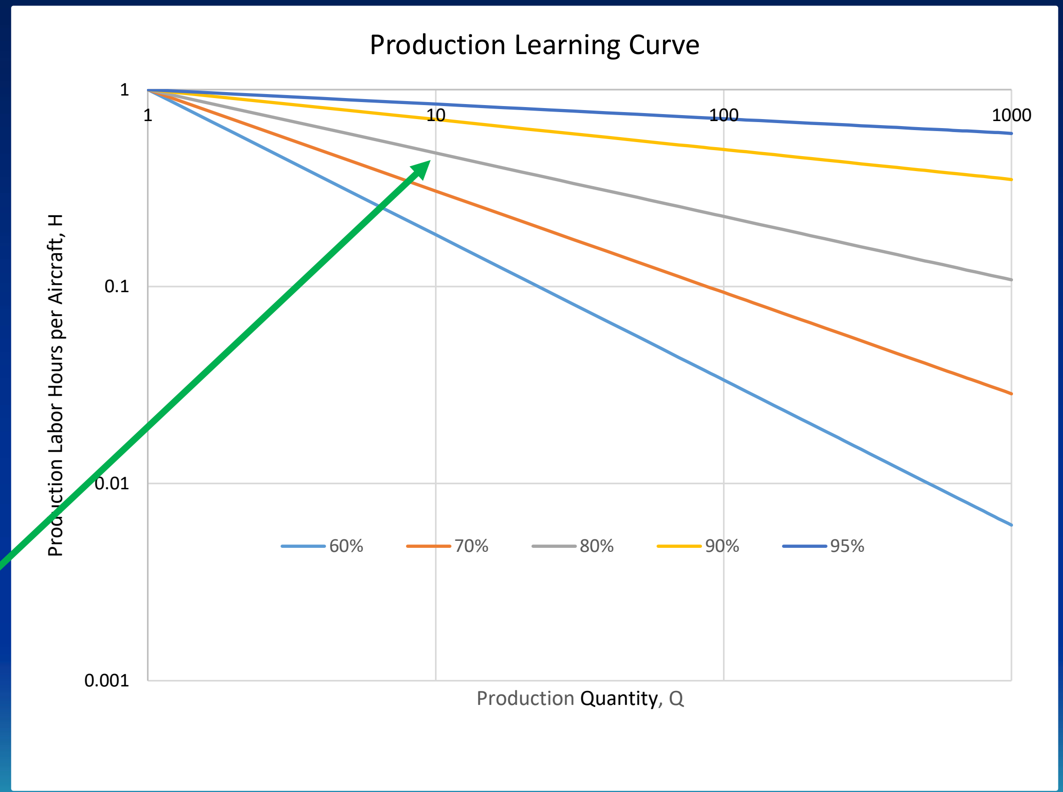


CER Variables

Airframe:

- Empty Weight
- Max. speed
- Lesser of total production quantity or 5 year production
- No. of flight test aircraft

Engine:

- Airframe production X no. of engines/aircraft
- Engine max. thrust
- Engine max. Mach no.
- Turbine entry temp.

Total Cost

Calculate costs by factoring hours by hourly rate R_X:

- Engineering cost (H_E R_E)
- Tooling cost (H_T R_T)
- Mfg. cost (H_M R_M)
- QC cost (H_Q R_Q)
- Dev. support cost (C_D)
- Flight test cost (C_F)
- Mfg. material cost (C_M)
- Engine production cost (C_{eng} N_{eng})
- Avionics cost ($C_{avionics}$)

Basis of DOC+I Model

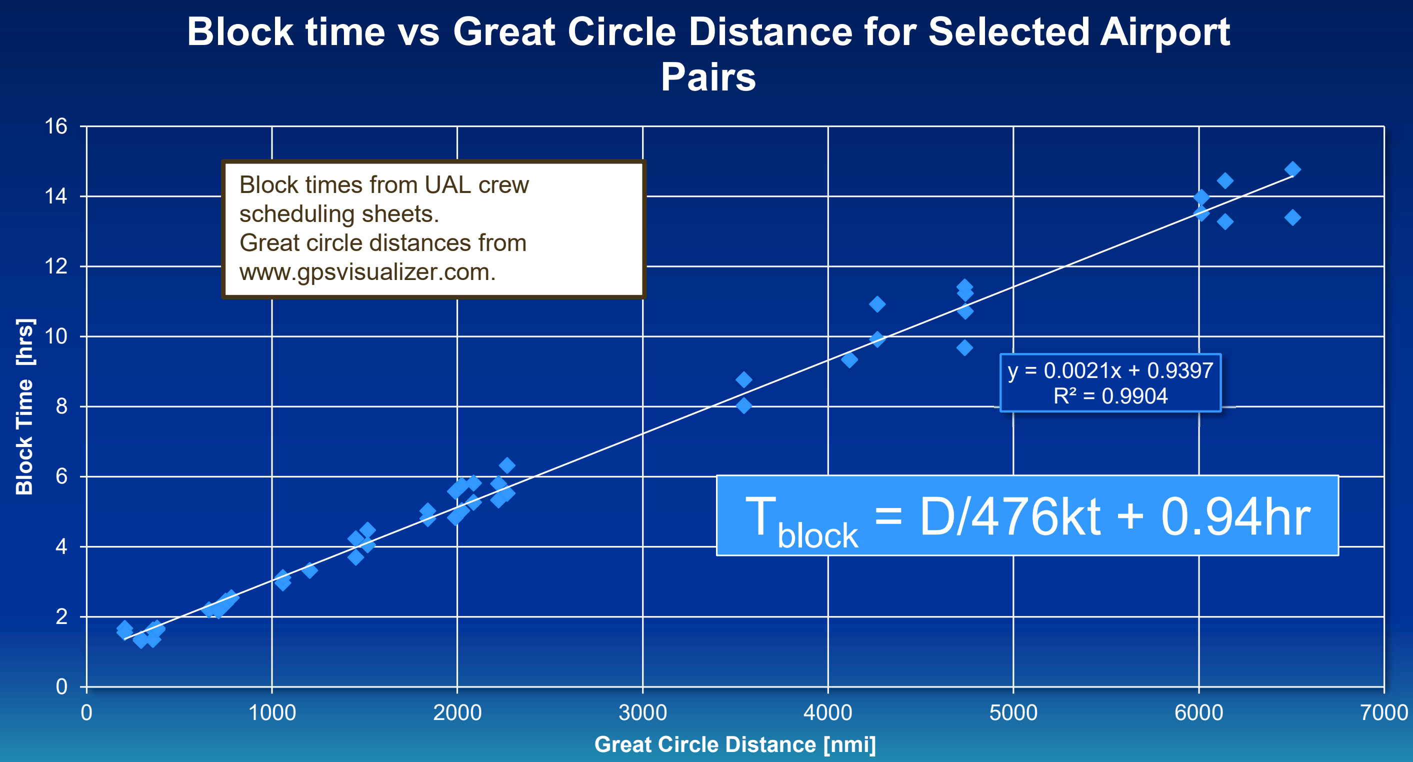
- Commercial aircraft operating cost
- Based on Direct Operating Cost + Interest (DOC+I)
- Bob Liebeck (Douglas) model – “Advanced Subsonic Airplane Design and Economics Studies”, NASA CR-195443, 1995
- Other inputs from Kostya Zolotusky (Boeing Capital Corporation)

Total DOC + I

Based on Air Transport Association ATA-67 method + Interest

Sum of
- Fuel cost
- Flight deck and cabin crew cost
- Total airframe maintenance cost
- Total engine maintenance cost
- Landing fee
- Navigation fee (for international flights)
- Depreciation, Interest, and Insurance

Block Time Estimation



Fuel

$$\text{Fuel cost} = \frac{W_f}{\rho_f} \times C_f$$

W_f = mission block fuel weight (excluding reserves [lb]
ρ_f = fuel density [lb/gal]. Use 6.7 lb/gal
C_f = fuel cost. Use value from
http://www.iata.org/whatwedo/economics/fuel_monitor/index.htm

Flight Deck Crew

$$\text{Flight deck crew cost} = T_{block} \times N_{fc} \times \left(C_{fc} + 0.532 \times \frac{W_{to}}{1000} \right) \times F_i$$

N_{fc} = number of flight deck crew (usually two, but three for some older airplanes, and four for transpacific flights)
C_{fc} = base flight deck crew cost of $440/hr
W_{to} = maximum takeoff gross weight
F_i = international salary premium (=1 for domestic, =1.1 for international flights)

Cabin Crew

$$Cabin\ crew\ cost = T_{block} \times N_{cc} \times C_{cc}$$

N_{cc} = number of cabin crew. For airplanes above 100 seats = 2+[(No. of pax seats) -100]/2. For < 100 seats, see FAR Part 121.391(a)
C_{cc} = base cabin crew cost of $60/hour (domestic), or $78/hour (international)

Airframe Maintenance Labor

Airframe maintenance labor cost

$$= \left(\left(1.26 + 1.774 \times \left(\frac{W_{airframe}}{10^5} \right) - 0.1071 \times \left(\frac{W_{airframe}}{10^5} \right)^2 \right) \times T_{block} + \left(1.614 + 0.7227 \times \left(\frac{W_{airframe}}{10^5} \right) + 0.1204 \times \left(\frac{W_{airframe}}{10^5} \right)^2 \right) \right) \times C_{ml}$$

$W_{airframe}$ = W_{empty} – (dry weight of all engines) [lb]
C_{ml} = Direct maintenance labor cost of $25/hr

Airframe Maintenance Material

$$\text{Airframe maintenance material cost} = \left(\begin{array}{l} \left(12.39 + 29.8 \times \left(\dfrac{W_{airframe}}{10^5} \right) + 0.1806 \times \left(\dfrac{W_{airframe}}{10^5} \right)^2 \right) \times T_{block} \\ + \left(15.2 + 97.33 \times \left(\dfrac{W_{airframe}}{10^5} \right) - 2.862 \times \left(\dfrac{W_{airframe}}{10^5} \right)^2 \right) \end{array} \right) \times 1.47$$

Engine Maintenance Labor

$$\text{Engine maintenance labor cost} = \left(0.645 + \left(\frac{0.05 \times F_n}{N_e \times 10^4}\right) \times \left(0.566 + \frac{0.434}{T_{block}}\right)\right) \times T_{block} \times N_e \times C_{ml}$$

F_n = Total net thrust at SLS for all engines
N_e = Number of engines

Engine Maintenance Material

$$\text{Engine maintenance material cost} = \left(25 + \left(\frac{0.05 \times F_n}{N_e \times 10^4}\right) \times \left(0.62 + \frac{0.38}{T_{block}}\right)\right) \times T_{block} \times N_e \times 1.47$$

F_n = Total net thrust at SLS for all engines
N_e = Number of engines

Landing Fees

$$\text{Domestic Landing fee} = C_{land} \times \left(\frac{W_{ml}}{1000}\right)$$

$$\text{International landing fee} = C_{land} \times \left(\frac{W_{to}}{1000}\right)$$

C_{land} = landing fee coefficient, \$2.20 for domestic, \$6.25 for international
W_{ml} = maximum landing weight

Navigation Fees

$$\text{Navigation fee} = C_{nav} \times 500\ \text{nm} \times \sqrt{\frac{W_{to}}{1000}}$$

International flights only

C_{nav} = navigation fee coefficient, assumed \$0.20

Depreciation

$$\text{Depreciation per year} = (1 - R) \times \left(\left(\frac{C_{af}}{P_{af}} \right) + S_{af} \times \left(\frac{C_{af}}{P_{af}} \right) \right) + \left(\frac{C_e}{P_e} \right) + S_e \times \left(\frac{C_e}{P_e} \right)$$

R = residual fraction for airframe and airframe spares
C_{af} = airframe cost (from Rand DAPCA model, next slide)
P_{af} = airframe life (nominally 15 years, but 20 to 25 years not unusual)
C_e = engine cost ($) x no. of engines. If actual not available, use Ceng from DAPCA)
P_e = engine life (assume 15 years)
S_e = engine spares (assume 0.23 x engine cost)

Airframe Cost

$$C_{af} = \frac{H_E R_E + H_T R_T + H_M R_M + H_Q R_Q + C_D + C_F + C_M + C_{avionics}}{Q}$$

From Rand DAPCA model

$$\text{Depreciation per trip} = \frac{\text{Depreciation per year}}{\text{Trips per year}}$$

Short range aircraft = 2100 trips/year
Medium range aircraft = 625 trips/year
Long range aircraft = 480 trips/year

Interest

$$\text{Annual Interest} = \text{Interest rate} \times \text{Loan amount}$$

$$\text{Interest per trip} = \frac{\text{Annual Interest Cost}}{\text{Trips per year}}$$

Insurance

$$\text{Annual Insurance} = 0.0035 \times \left(\text{Airframe Cost} + \text{Engine Cost}\right)$$

$$\text{Insurance per trip} = \frac{\text{Annual Insurance}}{\text{Trips per year}}$$

Insurance

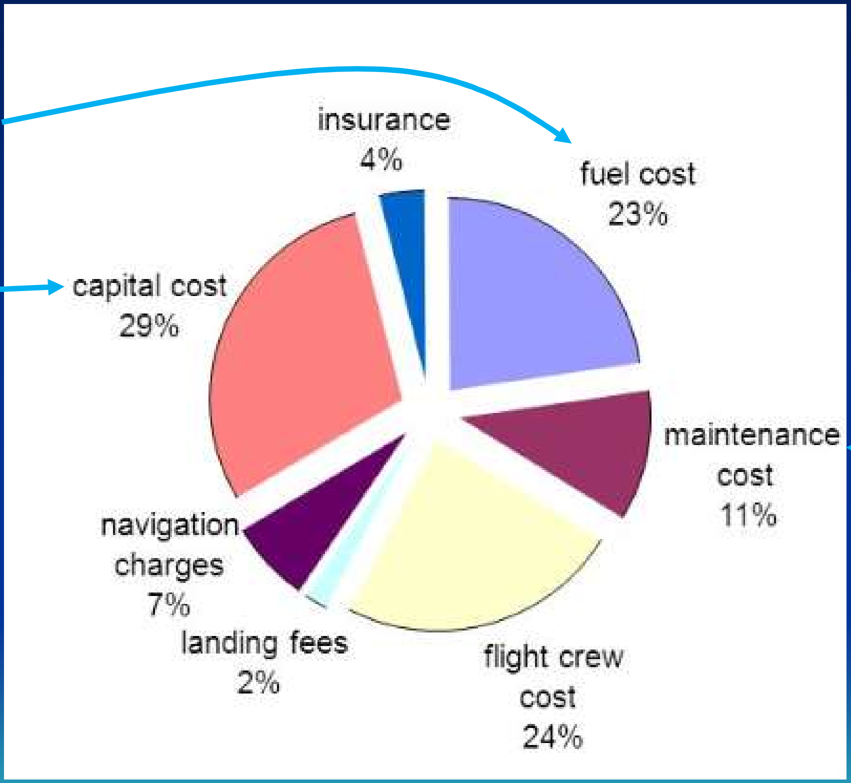
$$\text{Annual Insurance} = 0.0035 \times (\text{Airframe Cost} + \text{Engine Cost})$$

$$\text{Insurance per trip} = \frac{\text{Annual Insurance}}{\text{Trips per year}}$$

Typical DOC + I Breakdown

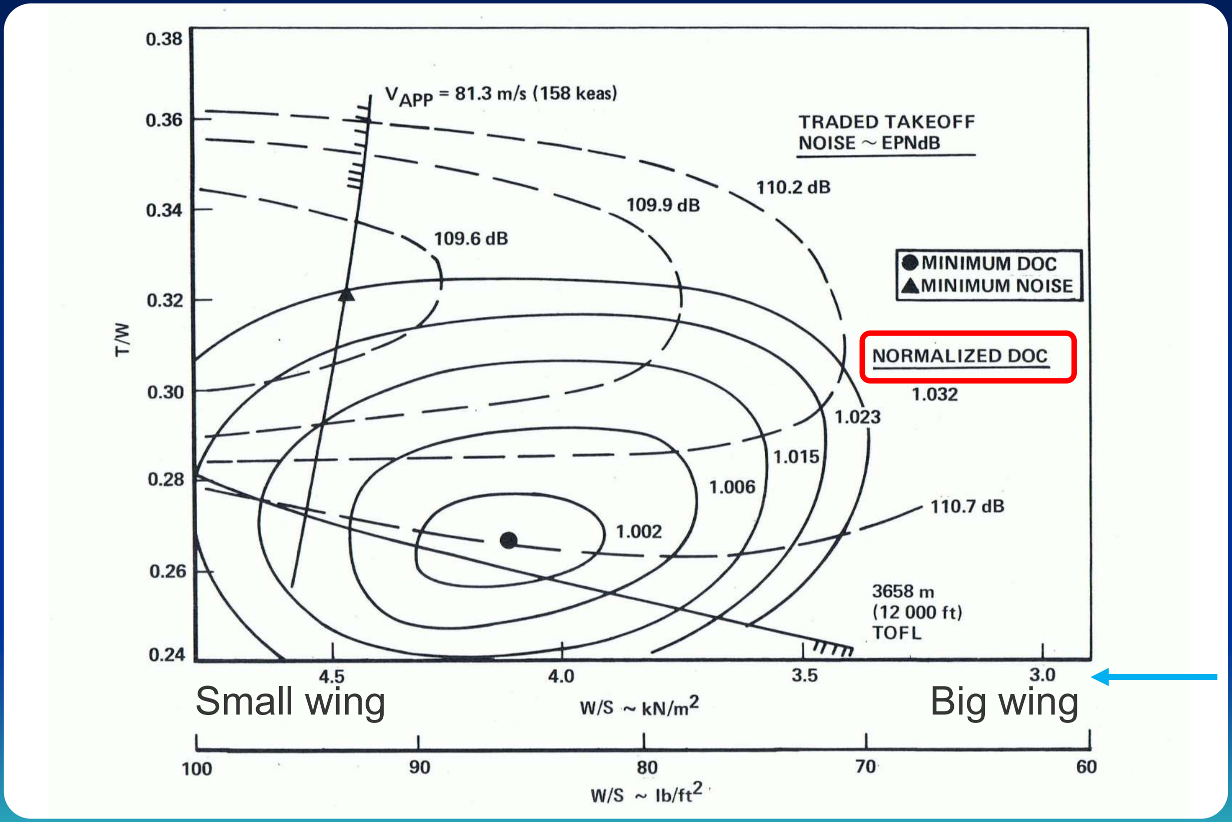
Cost breakdown strongly dependent on cost of fuel

Capital cost includes depreciation and interest



In 1960s, maintenance cost was about 25%

DOC Knothole Plot for SST with Noise Contours

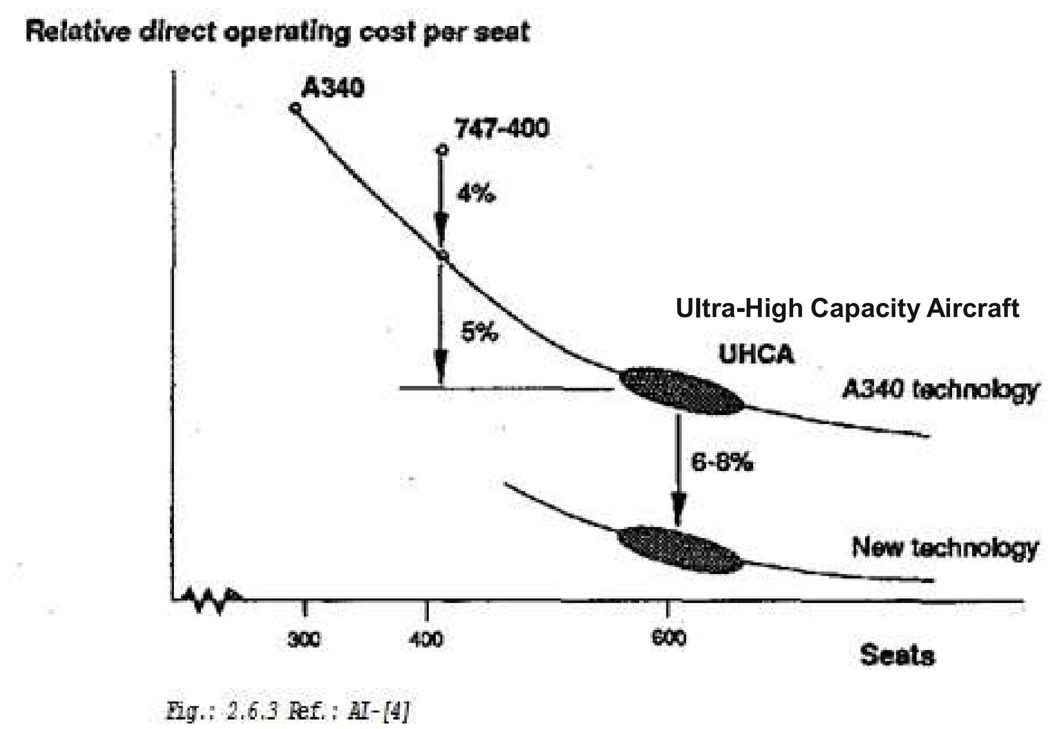


Note that horizonal axis is reversed

DOC is not everything

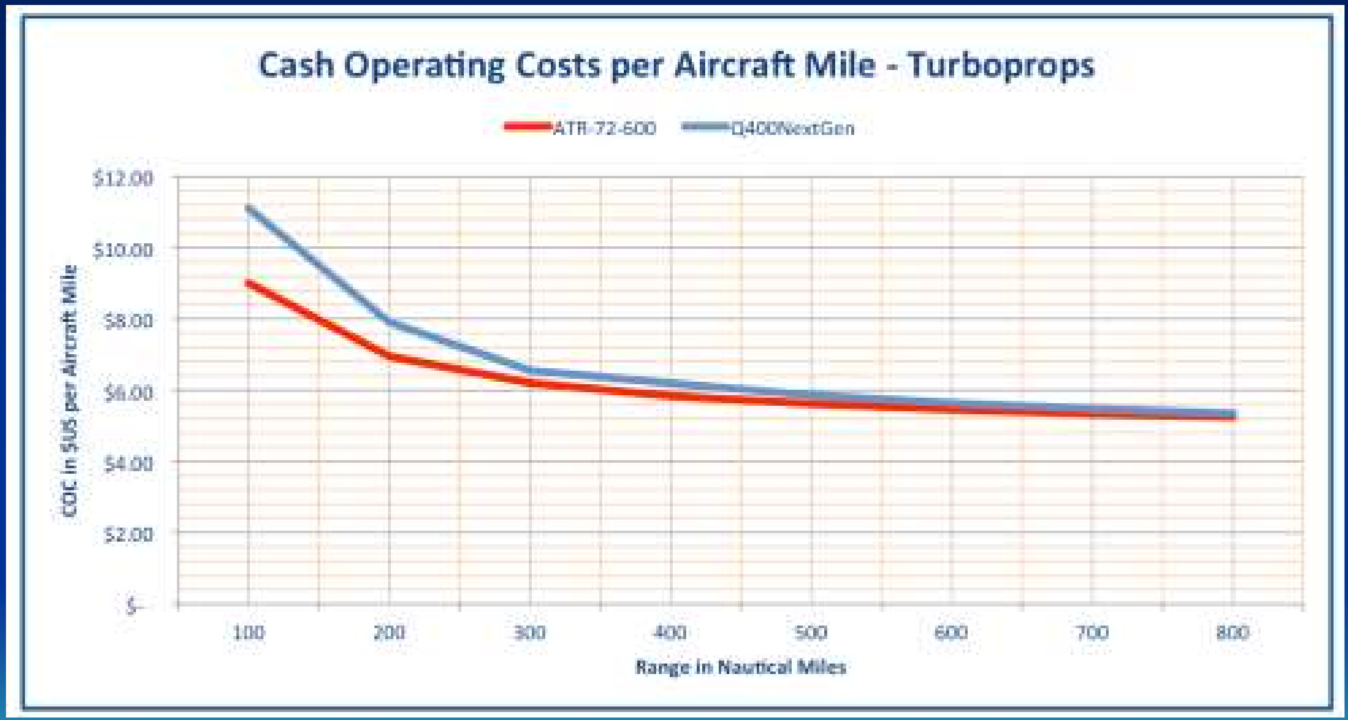
Must also consider

- Market fragmentation
- Frequency of flights between city pairs
- Airport accessibility

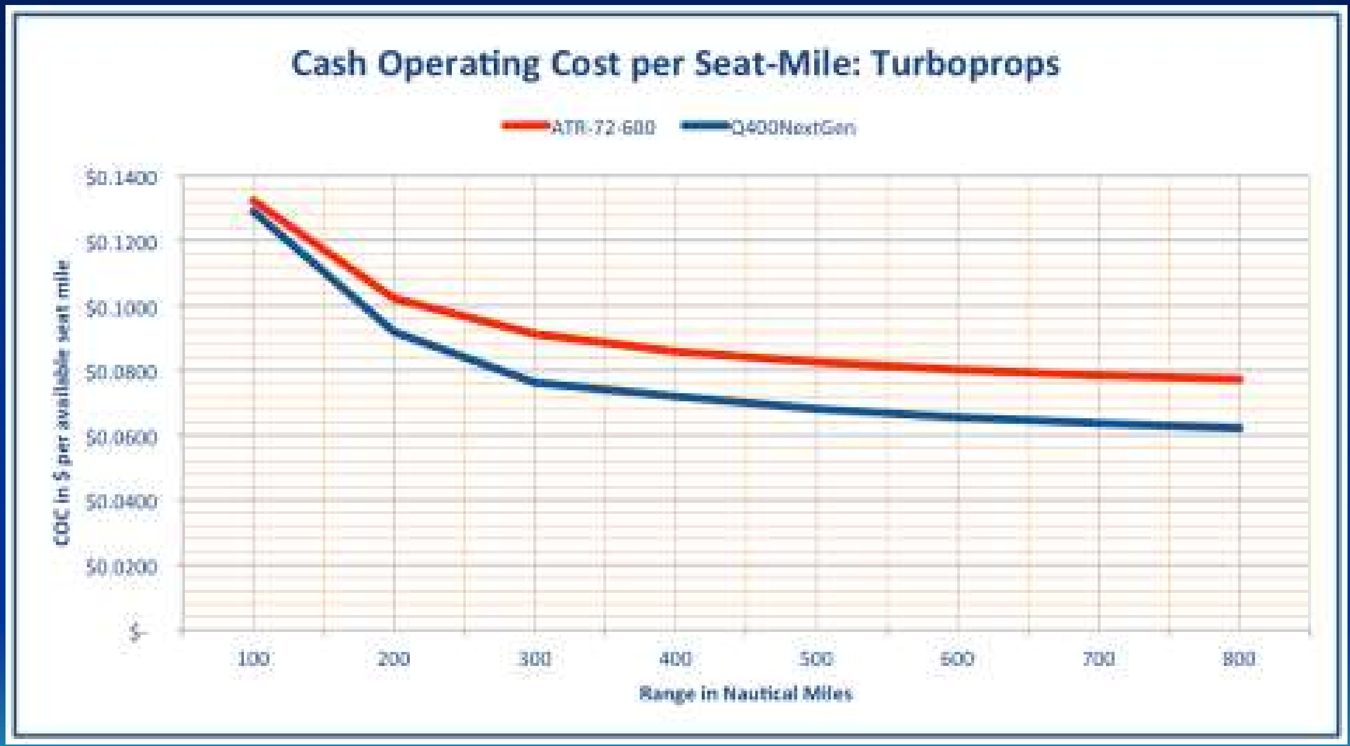


Author: Hajo Libor http://www.a380-design.com/market-analysis/airlines/operating-cost-considerations/

Cash Operating Cost



Cash Operating Cost



ADAC
Aircraft Design & Consulting

Cost Analysis

The End